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PLANNING, CONSTRUCTING, AND OPERATING FOREST-FIRE LOOKOUT SYSTEMS IN CALIFORNIA

By

S. B. SHOW, *regional forester*, California Region; E. I. KOTOK, *director*, California Forest and Range Experiment Station; GEORGE M. GOWEN, *chief of fire control*, California Region; J. R. CURRY, *senior silviculturist*, California Forest and Range Experiment Station; and A. A. BROWN, *chief of fire control*, Rocky Mountain Region, Forest Service

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INTRODUCTION

The principles upon which a forest-fire lookout system should be based to meet such detection needs as occur in northern California were developed in a recent bulletin.[1] Proper application of these principles requires technical methods and apparatus which have since been the subject of special studies. These studies and the detection-planning program based upon them involving all the national forests of the California region have resulted in the development of practical methods and special technique—particularly in the making of visible-area maps and in the use of these maps to build efficient detection systems—that may well have a wider application. This circular not only explains these methods and their technique but discusses also alternative methods that may be helpful to those engaged in meeting similar problems under different conditions.

In the fire-protection system here described, the aim is to see, at a range of less than 15 miles, the starting point of every fire, rather than every acre of territory. In practice, this resulted in setting a standard of direct lookout coverage in mountainous territory of 70 to 75 percent of the territory in which it is known that fires are likely to occur and of 50 to 60 percent of the total forest area concerned. If this standard is attained, fires should be detected within 15 minutes after they start, under usual conditions of operation.

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[1] Show, S. B., and Kotok, E. I. PRINCIPLES OF FOREST FIRE DETECTION ON THE NATIONAL FORESTS OF NORTHERN CALIFORNIA. U. S. Dept. Agr. Tech. Bull. 574, 32 pp., illus. 1937.

PLANNING AND DEVELOPING A DETECTION SYSTEM

PRELIMINARY PROCEDURE IN DETECTION PLANNING

BASE MAPS

The first step in setting up a detection plan for any area is accurate mapping. If possible topographic maps should be provided as a base for mapping visible areas, but if they are not available, reliance must be placed on the best drainage maps that can be supplied. A scale of 1 inch to 1 mile is preferable, but 0.5 inch to 1 mile is satisfactory. Maps of larger or smaller scales cannot be used as base maps.

FIRE-OCCURRENCE ZONE MAPS

Following the provision of base maps, the next important step is to set up a basis for grading detection values. In the California work this took the form of constructing a series of fire-occurrence or risk-zone maps for each unit (usually a national forest or portion of a national forest). Individual fire reports were the basis of these fire-occurrence maps. The most recent 10-year record of man-caused fires and 20-year record of lightning fires were used. The procedure is, first, to sort the reports by principal causes, as lightning, smoker, camper, incendiary, railroad, and miscellaneous. In this sorting, all fires are disregarded that represent a risk subsequently definitely removed, such as past logging operations, or construction. When not significant in number, several classes of man-caused fires are grouped together as miscellaneous. Next, the point of origin of each fire is plotted, a separate quarter-inch map of the unit being used for each cause group. Different symbols are used on these separate cause maps for each of the two 5-year periods of the man-caused record and the two 10-year periods of the lightning record, to serve as a check on current trends. Red symbols are used for C fires;[2] otherwise size of fire is disregarded. When the plotting is finished, the result is a separate geographical record of occurrence for each cause of fire.

The distribution and pattern of spots on each of these records is studied in relation to the localities concerned. The characteristic places of origin of the man-caused fires in relation to routes of travel, man's habits, and the topography are particularly examined. In this way the distribution of the spots and the design of their patterns soon become intelligible and it is possible to outline by localities, and often within narrow limits, where campers' or smokers' fires, for example, are most likely to occur. Areas defined in this way are termed zones of occurrence. Points of origin of lightning fires must be zoned more mechanically; yet a 20-year record, where lightning fires have been frequent, also reveals definite trends. In practice, an attempt is made to place a boundary around a group of spots at one-half the distance between spots. These mechanical boundaries are subject to alteration by interpretation. Use of small-scale maps and relatively large spots facilitates the definition of patterns and so aids in revealing zone characteristics. It is sometimes helpful to examine the general pattern in miniature through a reducing glass.

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[2] Fires covering a total area of 10 acres or more are classified in national-forest records as C fires.

After the individual zone maps have been constructed by causes, they are combined into a single zone map for all causes. A sheet of tracing paper is placed in turn over each of the completed cause maps and the spot locations of all fires as well as the zone boundaries are traced. This procedure is continued until all cause zones have been combined on one tracing (fig. 1), forming in many cases composite zones overlapping two or more causes. Some additional zoning must always be done when this composite picture is brought together.

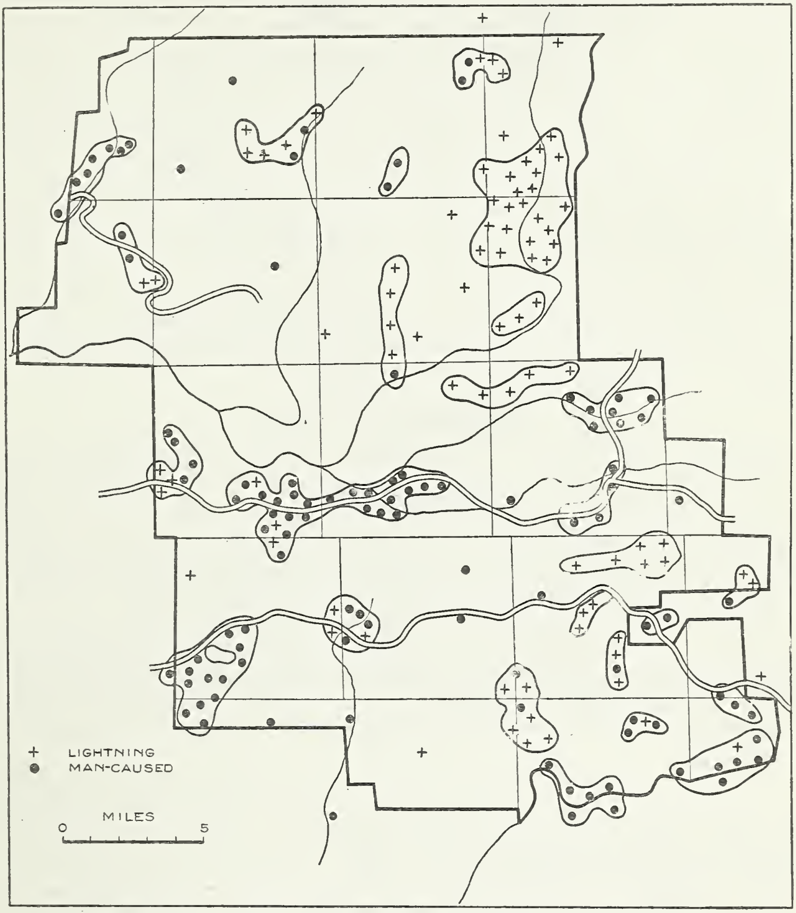

FIGURE 1.—Composite fire-occurrence zone map of a portion of a national forest.

The next step is the classification of the composite zones, by their degree or intensity of occurrence. The pattern of spots within each zone is carefully examined and boundaries are drawn in, subdividing the zone into portions carrying a similar distribution of spots, or intensity of fires. This is done in some detail and, though largely a mechanical process, the subdivision must be guided by intelligent judgment. For example, where apparent concentrations do not represent the whole period, they are not segregated unless they reflect a recently developed risk. Effort is made to include C fires in logical and important zones.

When this process is completed, each subzone is planimetered for area, the number of fires in it are counted (lightning fires from the 20-year period being treated as half fires), and the average fire occurrence for a 10-year period is computed and stated for convenience in terms of so many fires per thousand acres. The area, number of fires, and occurrence or intensity figure are then entered in each subzone. These data are later copied off on a tabulating sheet arranged to give a frequency distribution of occurrence figures by 1-fire intervals. That is, areas with an occurrence figure of 1.5 fires per thousand acres are listed in the 1-2 occurrence column, etc. This tabulation usually shows an uneven distribution of acreage throughout the range of intensity of occurrence. It is examined to determine the significant groupings that occur and intensity classes are defined accordingly. With this done, the average intensities of occurrence are determined on the basis of the total fires and total area within each class. On the map these averages are then referred to a color legend and the areas of each class are identified by a common color. For uniformity between forests separate colors are assigned to the following occurrence classes: 0.8 to 1 fire, 1.1 to 3 fires, 3.1 to 5, 5.1 to 10, and 10.1 plus fires per thousand acres for a 10-year period. Below the occurrence of 0.8 fire per 10 years, it is seldom feasible to define any pattern of risk; such areas are left uncolored, and an arbitrary occurrence figure of 0.25 is applied to them uniformly.

FIELD RECONNAISSANCE

The next important step is to make a field reconnaissance of the fire-control unit to determine the location of all promising lookout points. The completed fire-occurrence maps serve as a valuable guide in this survey. The object of the reconnaissance is to obtain the location of all points which apparently give lookout coverage of the risk zones, with emphasis on the zones of highest risk.

Inspection of contour maps will indicate many likely points for lookouts, but these should be checked in ground surveys, made by riding through important portions of the unit and noting the potential lookout points that are visible. In northern California, the opinions of local forest officers on the acceptability of points for detection are also sought.

If a relief model of the unit is available, it is most helpful in reducing the necessity for field reconnaissance. A few hours spent with it will furnish a better impression of the possibilities of lookout development than many days of field travel. (See further discussion on p. 18.)

The number of lookout points to be listed for mapping as a result of the reconnaissance depends on the size of the unit, the intensity of the fire problem, and the topography. It is unwise to discriminate closely on the quality of potential lookout points in the reconnaissance; a point that appears at first to be inferior in adjacent lookout possibilities may prove in the final analysis to have advantages sufficient to warrant its selection. As a rough guide, about five times the number of lookouts estimated as required for the final system should be mapped.

The final step in lookout reconnaissance is the preparation of a small-scale map showing the location of all the points to be mapped, and of written instructions on the best methods of travel to the points shown.

TECHNIQUE AND METHODS OF VISIBLE-AREA MAPPING

CHOICE OF METHOD

A lookout point is valuable in proportion to its effectiveness as a vantage point for quick discovery of all fires that start. Accordingly, the area and the identity of the territory visible from it are the very first facts to be sought. Visible-area maps furnish these facts, and their degree of accuracy fixes the dependability of any scheme of determining detection values. The results of study and trial of several methods of making these maps are evaluated in the following pages.

Field sketching is, in California, the standard method of making visible-area maps and is the method recommended under most conditions. The advantages of the method lie in its accuracy and economy and in the opportunity afforded in advance of obtaining all necessary information on developing the point. Occasionally a possible lookout point will be covered with a heavy stand of timber, making the preparation on the ground of a visible-area map difficult if not impossible. Sometimes it is impossible to visit in the field a point that must be mapped without delay. Under such conditions an office method known as the profiling method can be substituted. Two other methods are the photographic and relief-model. Although interesting in their technique, these are less adapted to general application since they require the availability of special equipment or facilities. In the following discussion the profiling method is presented first, since it introduces general principles that underlie all mapping of visible areas.

PROFILING METHOD

The accuracy of the contour base map largely determines the degree of accuracy of the finished visible-area map constructed by the profile method. Maps of a scale of 1 inch to 1 mile with a contour interval of 100 feet are preferable, but if they are not available, the half inch to a mile scale may be used.

Materials and equipment needed include contour maps, drafting board, cross-section paper, straightedge, drawing pencils, colored pencils, and triangles. The cross-section paper should be in sheets at least 15 inches long and 10 inches wide, divided into 1-inch squares and subdivided into tenths of inches.

The map is first mounted on the drafting board, and a line is drawn from the assumed observation point (*OP*) toward the edge of the map, in any convenient direction. The line should extend to the limits set for mapping visible areas—in California, 15 miles. Figure 2 shows a series of seven such lines already drawn.

A piece of cross-section paper is folded and fastened to the board as in figure 2. On it is entered a vertical contour scale, usually 0.1 inch to 100 feet, but varied to suit the topography.

Next, perpendiculars are dropped from each contour to corresponding points plotted on the paper. When these points are connected, the result is a profile of the topography on the line drawn. In crossing a stream or ridge, it is necessary to interpolate between the contours to obtain the conformation of the stream bottom or ridge top.

Areas visible from the *OP* (shown by the solid areas in fig. 2) may then be determined by drawing straight lines from the *OP* tangent to any topographic features shown on the profile that would form obstructions to the vision on the ground. These obstructions are ordinarily ridge tops, but may be a shoulder of the ridge upon which the *OP* is located. In drawing these tangent lines, the order of procedure is from the *OP* outward, toward the edge of the map. That portion of the profile between the top of one ridge and the point where the line of sight strikes the adjoining slope in the direction removed from the *OP* will be "invisible." Where ridges are so high that all topography in the direction removed from the *OP* is invisible, the profile is discontinued. Finally, the upper and lower sections of each visible section of the profile are projected to the base map by perpendiculars and connected on the profile line by a colored pencil line.

After the completion of the first profile, a new line is drawn on the map 3° to 7° below the first and the process repeated. Following the completion of the second profile, the boundaries of the seen areas defined by colored lines on the two profiles should be completed by interpolation and the areas themselves blocked in with colored pencil. The accuracy of the result depends upon the skill of the draftsman and the distance between the profiles. While learning the method, the operator should draw profile lines not more than 3° apart, and increase the spread to 7° only as his increased skill and experience permit. The number of profiles required depends upon the topography and upon the working radius of the map. For visible-area maps prepared by this method to a distance of 15 miles in the mountainous forest regions of California, an experienced mapper will need to make between 50 and 60 profiles.

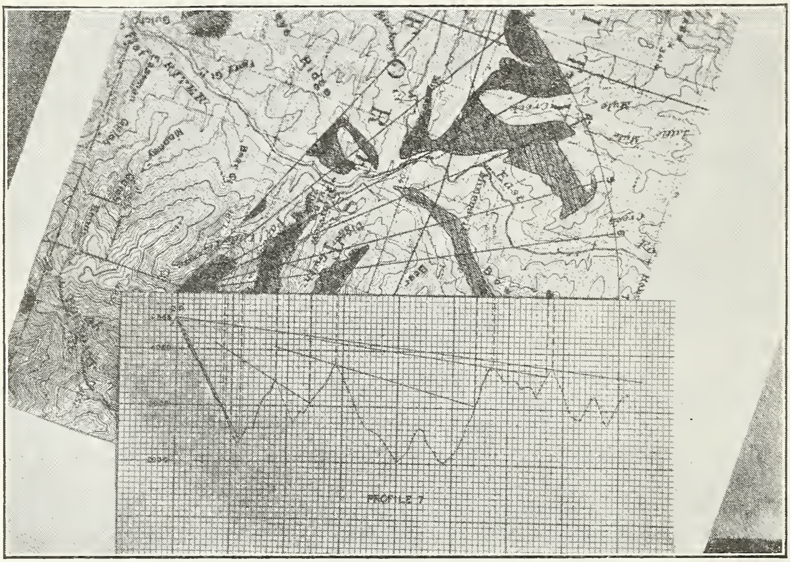

FIGURE 2.—A visible-area map in process of preparation by the profiling method. The visible areas have been blocked in for emphasis.

With experience, the operator learns many short cuts to speed the work. It is not necessary, for example, to plot the entire profile to determine the visible limits. As soon as the top of the first visible ridge is plotted, the line representing the line of sight is drawn tangent to the ridge top. The draftsman next examines the contours along the profile line to determine the first elevation which will be visible, and continues the plotting from that point. Sections of the profile shown in figure 2 by dotted lines would not be plotted by the experienced draftsman.

A spacing of profiles which gives sufficient accuracy near the lookout may at the outer limits of the map be too wide to permit accurate blocking in. When this is the case, it is often possible to interpolate profiles beginning at the top of midway ridges known to be visible and extending outward to the limits of the map, a practice resulting in considerable savings in time without loss in accuracy.

THE CONSTRUCTION AND USE OF THE PROFILING BOARD

A device known as a "profiling board" greatly expedities the preparation of maps by this process. It consists of three parts, base, arm, and slide, as shown in figure 3. The base is a flat sheet of pyralin or heavy celluloid 18¾ by 10 inches, if 1-inch scale maps are used. On its bottom surface, cross-section paper is fastened so that the lines of the paper are visible through the pyralin. The surface of the pyralin is slightly roughened or buffed to take pencil marks. A small celluloid tab is fastened at the upper left-hand corner of the base and pierced with a pin at the intersection of the upper edge of the board and the first vertical line of the cross-section paper (fig. 3, *A*).

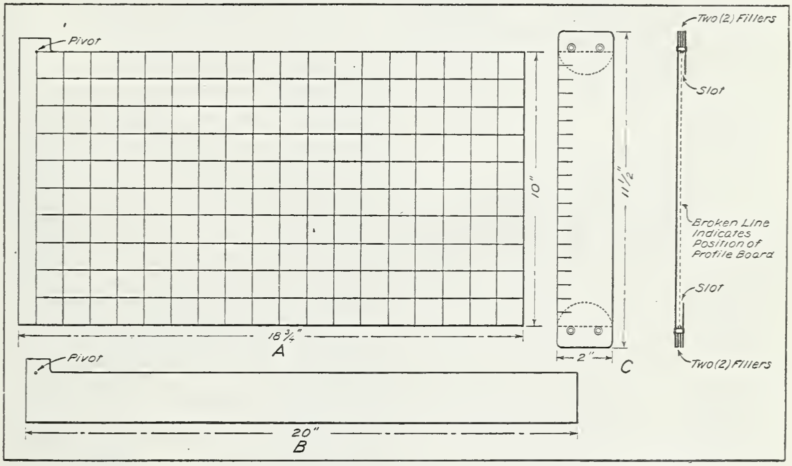

FIGURE 3.—Details of construction of profiling board: *A*, base; *B*, arm; *C*, slide.

The arm of the board is a pyralin straightedge, 20 by 1¾ inches. A tab similar to the one on the base is punctured at a point in line with the upper edge of the arm to permit pivoting the arm at the elevation of the *OP* (fig. 3, *B*).

The slide portion of the board consists of a strip of pyralin 2 inches across, to which has been attached, at each end, a flange of the same material, so constructed that the slide may be moved backward and forward across the base while remaining in vertical alinement. The front surface of the slide is roughened to take pencil marks and ½-inch divisions are marked on the surface to agree with the main divisions of the cross-section paper of the base (fig. 3, *C*).

The procedure in using the profiling board is first to enter the scale of elevations appropriate for the *OP* on both the left edge of the board and on the slide, beginning usually at the pivot point with the even 100-foot elevation above that of the *OP* and numbering down. Then the base is pivoted at the *OP* on the map by means of a pin or needle and an azimuth line is drawn on the map out the desired distance from the *OP*. With this done, a profile is plotted just as described with profiling paper out to the first intervening ridge. Here the ordinary plotting of contours is discontinued, and we are ready to use the arm. A pin hole is pricked at the exact elevation of the *OP* on the scale below the pivot, and the arm is pivoted at this point, then swung around until it is tangent to the tip of the first intervening ridge on the profile just plotted, and fastened there with drafting tape. Next the slide is fitted to the board at this point of tangency, and while it is moved slowly to the right the changing elevations on the slide at its intersection with the fixed arm are carefully compared with the contour elevations on the map, intercepted above. The point sought is the first map contour the elevation of which agrees with that indicated by the intersection of the arm with the slide. This is the first point visible behind the ridge.

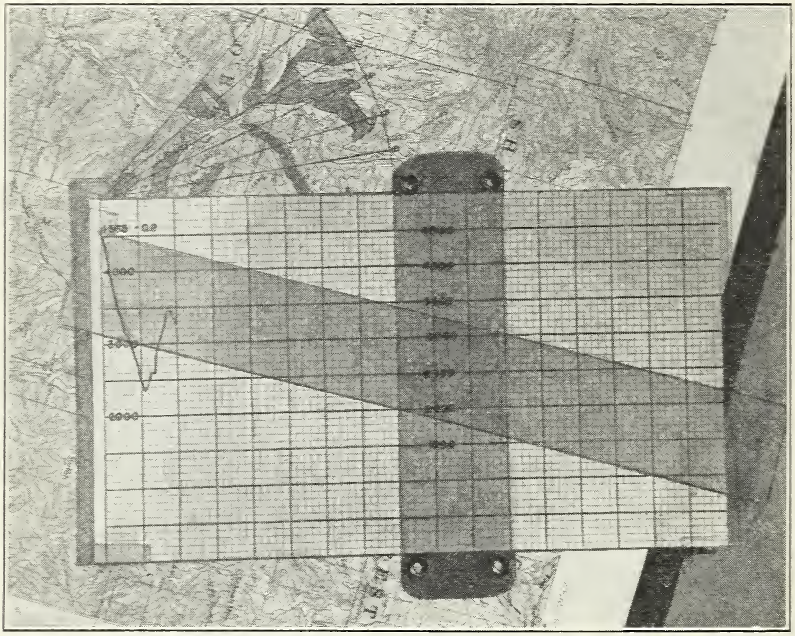

FIGURE 4.—Operation of profiling board; visible area in process of construction on board has already been blocked in in color on map to make outline clearer in illustration.

The portion of the line on the map from this point on to the top of the next ridge is visible and should be marked in color. With the arm then shifted until it is tangent to the top of the second ridge, the procedure may be repeated. Note that no contours have been plotted on the base from the top of the first intervening ridge. The procedure as outlined above is continued to the limits of the map. Figure 4 shows the profiling board in use.

With practice in their use, profiling boards will be found to speed up the work greatly, and their construction is recommended where any considerable amount of profiling is to be done. They are particularly convenient for running short profiles in the outer portion of the map where the main profile lines are too far apart to allow accurate blocking in.

The accuracy of visible-area maps carefully made by the profile method depends directly on the accuracy of the topographic base used. Errors in depicting visible area by profiling are greatest in the immediate vicinity of the *OP* and decrease with distance from it. There is always a possibility that some sharp local obstruction, such as a rock outcrop, may unavoidably cut the view in one direction and that this can be determined only by occupying the observation point. Normally the error is confined to the first mile or two and the total acreage shown as visible is substantially correct. Maps made by profile should always be checked on the ground before the point is finally accepted for detection use. This is the chief defect in using the profile method, since the total time required is more than that taken in field sketching the whole map from the *OP*. When a very accurate topographic map is available, however, and the sketcher is inexperienced, more detail and a greater final accuracy is attained by profiling the map first, and then checking it systematically on the ground.

FIELD SKETCHING

Sketching from the observation point is the most direct, rapid, and altogether satisfactory method of obtaining visible-area maps. Where the mappers have adequate training and experience, field sketching results in good maps obtained with a minimum of effort. The time spent in the actual sketching is less than that required for profiling and, once completed, the maps may be used directly without further check. If the base maps available are likely to be inaccurate, field sketching is a far safer method to employ, since in field sketching the mapper has a full opportunity to check the map's accuracy.

In situations where field sketching is not possible, as on observation points covered by dense stands of timber, the profile method must occasionally be used. Field maps are sometimes made from such points, however, by sketching from trees, or if the timber is not too dense to permit a partial view in all directions, by shifting the board frequently. Under California conditions, lookout points are usually either thinly timbered or barren, making field sketching altogether practicable.

MEN AND MATERIALS

The following equipment is necessary for sketching visible areas in the field: Maps, tripod and board, alidade, Abney level, 50-foot tape, drawing pencils, colored pencils, pins, thumbtacks, erasers, slide rule, tracing paper, binoculars, colored glasses, and a knapsack or pack board.

The scale of the maps used governs the size of the board and tripod. One inch to 1 mile maps are recommended for field sketching, and for this scale a 20- by 26-inch standard drawing board may be used by adapting it to fit a light collapsible-leg tripod. If maps of half an inch to a mile are used, a smaller board and lighter tripod are practical.

The size of the alidade is also dependent on the scale of the maps. For 1-inch maps, the alidade should be at least 15 inches long. Good-quality prismatic binoculars magnifying six times are a useful tool in this work.

The number of mappers to be employed will depend on the number of maps to be made and the time available for the survey. Two to four maps per week may be made by a trained sketcher. Ordinarily, it will be impossible to obtain enough men with experience in field mapping and it will be necessary to hire inexperienced men and train them. The training should cover a period of 1 to 2 weeks and should consist of both classroom instruction and field practice.

DETERMINING MAP LOCATION

The mapper's first problem is the correct determination of his map location in cases where this cannot be fixed certainly by inspection. Unless the correct *OP* is used, the map cannot be oriented. The determination is made by a solution of the three-point problem, for which several methods may be found in any surveying text; one such, using graphic methods, is explained here.

A sheet of tracing paper is tacked over the mounted map and through it a pin is stuck at an arbitrary location to serve as a point of orientation. Three peaks or other prominent topographic features identifiable on the map and subtending wide angles, are then chosen by the observer as targets. The targets should be conspicuous and sharply defined and preferably should be triangulation points. The alidade, held flush against the pin, is sighted at one of the selected targets and a fine pencil line is drawn along it to the edge of the board. This procedure is repeated in turn for the other targets, each line being labeled with the name of the point. The tracing paper is then loosened and moved about over the map until the lines drawn toward each target pass directly through the map location of that target. When lines and map points all agree, the point on the tracing paper where the lines come together will be exactly over the correct location of the observation point and can be pricked through the tracing paper onto the map. If the map, when oriented on any one triangulation point, is found not to be in correct orientation for other points, it is assumed that the solution of the problem is in error and it should be repeated. When the map is finally oriented, the work of sketching may begin.

PROCEDURE IN SKETCHING

Sketching of visible areas consists essentially in identifying seen area on the ground, transferring the boundaries of the area to the map, and finally blocking in these visible areas in color. While the sketching technique can best be learned through field practice, certain principles are discussed here to introduce the subject and to give the beginner methods of solving the most common types of problems which confront the sketcher.

The mapper selects for his initial work a sector of 20° to 30° where the atmospheric conditions are best for work and marks this sector definitely on the map with pencil. Because of the influence of the sun on the visibility of topography, this will ordinarily result in mapping of areas to the west in the forenoon and to the east in the afternoon. Sketching should begin near the observation point and should proceed in an orderly manner from there outward.

Figure 5 has been prepared to illustrate the main features of visible-area sketching. In the upper sketch of this figure the points *A* and *B*,

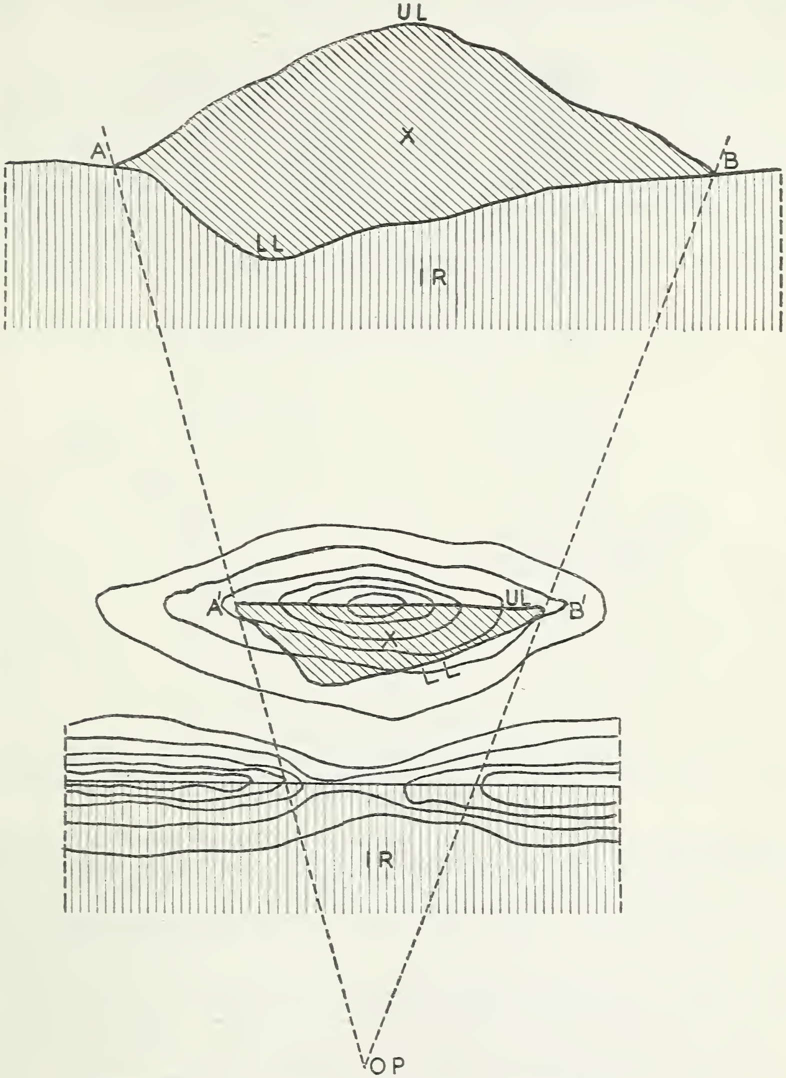

FIGURE 5.—Diagram of section of topography and section of map to illustrate methods of sketching visible areas. *X* is a visible ridge behind *IR*, an intervening ridge. *LL* is a lower limit and *UL* the upper limit on *X*. *A*, *B*, are points marking the horizontal limits of the visible area on the ground. *A′* and *B′* mark the horizontal limits of the visible area on the map.

where the ridge *X* first becomes visible, represent the horizontal limits of the visible area as they appear to the eye. *UL* and *LL* refer respectively to the upper and lower vertical limits of the visible area.

The sketching of a small visible area is illustrated by the lower sketch in figure 5. The first step consists in identifying on the map the ridges *X* and *IR*. Next, the points *A′* and *B′*, marking the horizontal limits of the visible area on the map, are located by placing the alidade against the pin marking the *OP*, sighting at each of the points *A* and *B*, and drawing a pencil line along the alidade to the point of intersection with the top of the ridge *X* on the map. These intersections fix the location of both horizontal limits of the visible area.

In figure 6 it is obvious that, to define the upper limit of the ridge *X* it is only necessary to connect the points *A′* and *B′* in figure 5 with a line along the top of the ridge *X*. To locate the boundary of the lower limit of visibility on ridge *X* is more difficult, requiring both skill and experience on the part of the mapper. The usual practice is first to sketch in the line of lower limit, using the appearance of the topography and the relative elevations of the *OP* and *IR* as guides, and follow with the accurate checking of key points by an instrumental means to be explained later (p. 15).

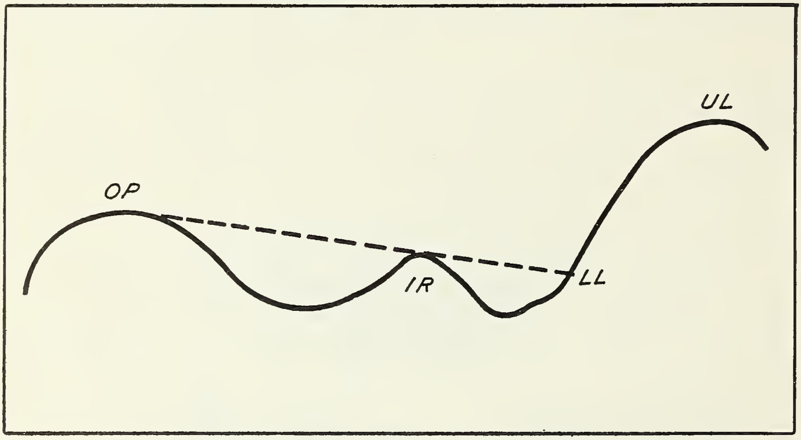

FIGURE 6.—Profile view of topography seen in figure 5. To locate altitude of *LL* on the map requires special computation.

Distinctive points on the line of lower limits are quickly lined in by alidade sights, and help to determine the correct shape of the visible area, but this does not aid in determining the correct elevation of the line of lower limit. The usual method of judging these elevations approximately is to make mental computations of the fall or rise of the line of sight from the relative elevations and locations of *OP*, *IR*, and *LL*. If the *OP* is higher than the *IR*, then the line of sight is falling and the elevation of the *LL* is lower than *IR*. Suppose that the elevation of *OP* in figure 6 is 5,000 feet, the elevation of *IR* is 4,600 feet, and the horizontal distance between the *OP* and *IR* is 2 miles. It is apparent, then, that the line of sight drops 400 feet in 2 miles or 200 feet per mile. Now, if the distance between *IR* and the approximate location *LL* is measured, the difference in elevation between *IR* and *LL* may be computed. If, in figure 6, this distance is 0.75 mile, then the approximate elevation of *LL* will be 0.75×200 or 150 feet lower than *IR*, or 4,450 feet. Mental computations of this kind are a considerable aid to the judgment.

When *IR* is higher than *OP*, the line of sight is, of course, rising, and the elevation of *LL* is higher than that of *IR*. If points on *IR* are lower than *OP* or at the same elevation, then the elevation of *LL* will be lower or equal.

Although figure 5 illustrates a simple case of visible-area sketching, all problems met with in the field may be reduced to the same elements discussed above, the determination of the three limits, horizontal, upper, and lower. Usually visible areas consist of views of ridges which are limited by the visible ridges in front of them, but there is one case which differs somewhat from this, where *OP* affords a view of a valley or plain in which blind spots occur behind low ridges or buttes. In such cases the blind areas rather than the visible areas are delineated, as shown in figure 7. The upper limit of the blind area is determined in the same manner as the lower limit of a seen area as explained above. The lower limit of the blind area is located by the top of the ridge or butte and the horizontal limits are obtained by alidade sights at the base of the butte.

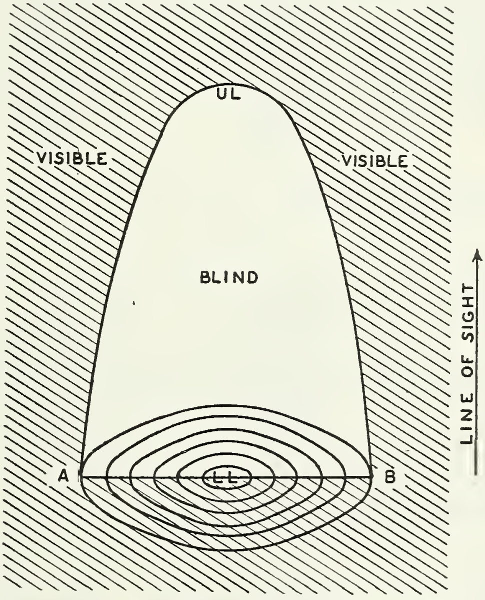

FIGURE 7.—Horizontal projection of topography, where line of sight over *IR* falls on a relatively level plain, illustrating the delimiting of blind area in territory generally visible.

Sketching may be facilitated by conceiving seen areas as those which would be illuminated if a strong light were placed on the observation point, while the blind areas would correspond to those in shade (fig. 7). This is particularly useful in sketching a complicated line of lower limit where the shape of the line may be regarded as being determined by the shadow of the intervening ridge.

Figure 8 illustrates the forms which the shadow of a butte of regular proportions assumes under different conditions of illumination and background. The forms on the right (*C*, *F*, *I*) illustrate the shape of a shadow when *OP* is higher than the butte. Note that in these cases the observer can see slightly over the top of the butte and that the boundaries of the blind area converge. In the central row (*B*, *E*, *H*) *OP* and the butte are at the same elevation. Here the boundaries of the blind area are parallel and the blind area begins exactly at the ridge top. In the third row of figures (*A*, *D*, *G*) the *OP* is lower than the butte. In these cases the observer cannot see to the top of the butte, and the boundaries of the blind area diverge. The effect of background upon the shape of blind areas is also shown.

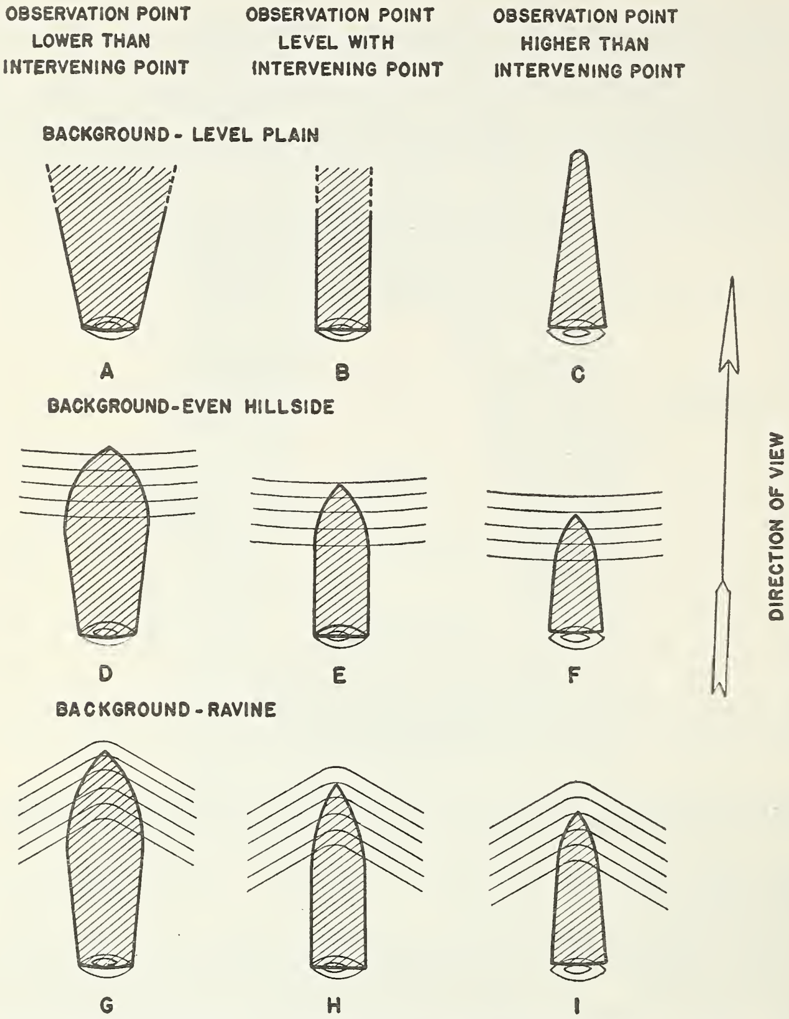
OBSERVATION POINT LOWER THAN INTERVENING POINT
OBSERVATION POINT LEVEL WITH INTERVENING POINT
OBSERVATION POINT HIGHER THAN INTERVENING POINT
BACKGROUND - LEVEL PLAIN
A
B
C
BACKGROUND-EVEN HILLSIDE
D
E
F
BACKGROUND - RAVINE
G
H
I
DIRECTION OF VIEW

FIGURE 8.—Forms of invisible areas projected against different backgrounds when the intervening point is a rounded hill of higher, lower, or equal elevation.

A careful study of these figures will aid the sketcher in delineating the line of lower limits of visible area, but it is essential, also, that he be able to check the dimensions of his sketch more accurately. In the following paragraphs an accurate method of checking these limits is explained.

DETERMINING VISIBLE-AREA CONTROL POINTS

A common problem in checking lower limits of visible area is illustrated in figure 9, where the correct location of *B* is required. As the line of sight is falling, it is apparent that *B* will be at a lower elevation than *IR*, the difference depending upon the angle of vision from *OP* to *IR*, and the distance between *OP* and *B*. The method of solving this problem is first to locate *B* by approximation, then to check the approximation, and to continue approximation and checking until the correct location is found.

In figure 9, the following information is available: The location of *A* (*OP*), the elevation of *IR*, and the distance from *A* to *IR*. The location of *B* (*LL*) is assumed. From these data the grade percent of the line of sight *AB* may be computed. By measuring the horizontal distance *AC* on the map and multiplying by the grade percent, the elevation of the point *B* may be determined. If this elevation does not check with the map elevation at the assumed location of *B*, then *B* is located incorrectly. Next, *B* is relocated and the process repeated until a location is obtained which gives the correct distance and elevation for the grade percent. Under ordinary methods, these computations are so laborious as to be unpractical, but by the use of the slide rule they may be solved very rapidly and with a sufficient degree of accuracy.

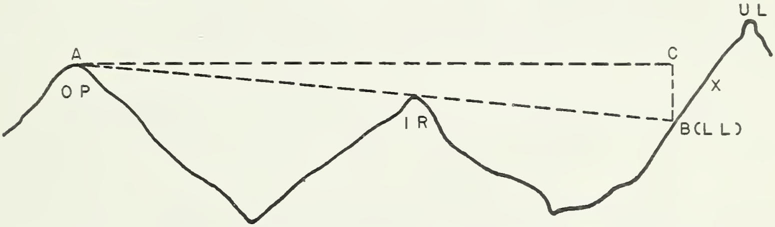

FIGURE 9.—Profile of a section of topography to illustrate methods of determining lower limit of visibility, or elevation of *B*. The angle *CAB* is known, and the distance *AC* may be approximated on the contour map. Computing *CB* should give elevation of *B* (or *LL*). Adjustment of the approximated distance *AC* may be needful to reconcile this elevation with contour map.

A polyphase slide rule as shown in figure 10 is used. The computations consist of determining differences in elevation in feet by multiplying distance by grade percent. Inasmuch as map distances are ordinarily measured in miles, this requires multiplying miles by 5,280, but an easier slide-rule operation is to divide by the reciprocal of 5,280 or 0.0001894. Since this factor is used constantly, it is marked permanently on the B scale of the slide rule by *M*, as shown. The equation to be solved on the slide rule may be stated:

$$e=\frac{gd}{M}$$

Where e = the difference in elevation in feet,
g = the grade percent,
d = the distance in miles.

Suppose the difference in elevation between *OP* and a point estimated to be 7 miles distant is desired. By an Abney level reading or through computation on the intervening ridge, the grade is determined as 3 percent. With these values, the formula becomes:

$$e=\frac{0.03\times 7}{0.0001894}$$

On the slide rule, set the index *M* opposite 3 on the A scale. Over 7 on the B scale, read an approximate 1,110 feet on the A scale. The determination of the decimal point is no problem in the field, as it is at once obvious that the difference in elevation is not 111, or 11,100, but 1,110 feet. If this difference in elevation of 1,110 feet at 7 miles does not agree with the contour elevation, then it is only necessary to move the slide slightly forward or backward until a combination of distance in miles and difference in elevation in feet is found which checks with the elevations and distances on the map.

For still more rapid computation, actual elevations may be printed in pencil on the A scale of the slide rule and changed for each *OP*, as in figure 10, where the slide rule has been marked for minus angles from an *OP* of 5,200 feet elevation. Occasionally the computations involve a rising line of sight. For these points a supplementary A scale may be printed on the lower edge of the slide rule as is also shown in figure 10.

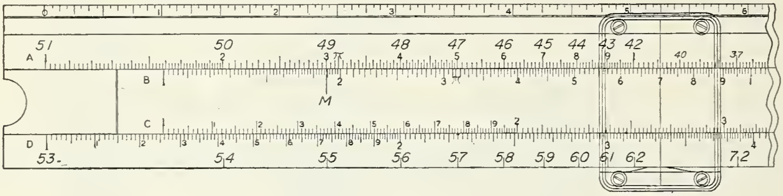

FIGURE 10.—Mannheim slide rule adapted to the solution of visible-area problems. Elevation figures, as 51, 50, 49, etc., above the A scale and below the D scale, are entered in pencil for each point mapped. The index M is 0.0001894, the reciprocal of 5,280, converting miles to feet.

The slide rule offers a ready method of computing the grade percent when, because of excessive distance, it is inadvisable to use the Abney or when the difference in elevation is so slight as to make it difficult to get an accurate reading. The slide is set at the elevation of the intervening ridge on the supplementary A scale. When the distance between the intervening ridge and the *OP* as shown by the map is set on the B scale beneath the slide, the grade percent can be read over the factor *M*. Without further adjustment, the slide rule is also in position to solve the correct location of the lower limit of visibility beyond the intervening ridge.

In some cases, as when an intervening ridge cuts off a flat or rolling area, it is simpler to estimate e and find d as in the formula $d=\frac{eM}{g}$ The slide rule process is exactly the same as before except that the slide is set at e on the A scale and d is read immediately below on the B scale. Here, again, if d and e cannot be reconciled on the map, the slide must be adjusted right or left for a closer approximation.

SKETCHING ON FLAT MAPS

On forest units where contour maps are not available, a good drainage map can be used for visible-area sketching, as has been shown by Shank.[3]

It is desirable in sketching on a drainage base to use mappers who have had considerable experience, since there is much greater demand for judgment in the use of a flat base than in sketching on a contour map. The alidade remains a useful tool, but the Abney and slide rule are of little value. The mapper must locate the ridges as well as the blind areas from the appearance of the topography and the location of the streams and culture shown on the map. It cannot be expected that these maps will have the degree of accuracy of those on a contour base. It has been demonstrated, however, that reasonably satisfactory results can be obtained, and that if better maps are not available, the use of flat maps is justified.

LOCATION AND ELEVATION OF LOOKOUT STRUCTURE

If the mapper finds, because of the presence of timber or the conformation of the point, that an elevated lookout structure is required, he is expected to determine the proper height at which the lookout must be built. Where the obstruction is a stand of timber too heavy to be cut, the Abney level can be used to determine in advance which trees will obstruct the view at different tower heights and the general height of the crown canopy. Exceptionally high trees may be marked for topping.

Where the irregularities of the peak are such that important areas beneath the peak cannot be seen, the mapper first chooses what appears to be the most logical location for the lookout house, setting up at this point a pole to which a marker is attached at eye height. He then goes down slope toward the important blind area until it becomes visible. From this point two Abney readings are made, the first to the lower limit of the desired visible area and the second to the eye-height marker on the pole. Next the observer measures the horizontal distance to the pole, preferably by tape. With these data, the following equation may be solved:

$$e=(g_1-g_2)d$$

In which—

e=the indicated elevation required for the lookout,

g_1=the grade percent to the lower limit of visible area,

g_2=the grade percent to eye height at the proposed location,

d=the horizontal distance between the observer's station and the proposed lookout location.

Where it is necessary to make more than one computation of this kind, the highest elevation obtained is the one to use, unless it proves to be much in excess of the others. In that case the location of the lookout proposed can be improved by moving it down slope toward the area requiring this high elevation, and again testing it by measurement and computation in behalf of the other areas. At present, in

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[3] SHANK, H. M. VISIBILITY MAPS BY FIELD SKETCHING. Jour. Forestry 29: 526-532. 1931.

California, the highest elevation considered practical for a standard 14 by 14 lookout house is 30 feet. Wherever possible, the lookout structure elevation is kept below this figure.

OTHER FIELD DATA

Other factors, in addition to range of visible area and the necessary height of the lookout observatory, affect the feasibility of a point for development as a lookout. The mapper is instructed to make complete notes on the ground, covering such information as present accessibility, and the best routes for new road or trail development, the length and location of telephone line needed, the nearest water available, difficulties of anchorage of a tower or unusual difficulties of constructing the house on the site, and the cost of removing obstacles to the vision such as trees or rock points. Such notes should never be neglected, since an extra trip to the point may otherwise be necessary.

PHOTOGRAPHIC METHOD

The photographic method of developing seen-area maps is based on the use of the phototransit camera as developed by Osborne of the Pacific Northwest National Forest Region.

This camera records the complete panorama from a vantage point by means of three 126° exposures, allowing an overlap of 3° on each side. It is capable of exact leveling and orientation and records photographically on each film and print azimuth and vertical angle graduations in degrees. Index pointers at each side establish also a level line across the prints. Vertical angle and azimuth, with reference to any position occupied —the essential data for the development of a visible-area map—may thus be measured directly from the finished picture. Since a camera of this type was available in the California Region, thorough tests were made of the best methods and of the possible advantages of making visible-area maps from phototransit pictures.

The first attempt was to follow essentially the technique of the field-sketching method described in the foregoing pages with the pictures substituted for the actual landscape, a vertical angle scale for the Abney level, and a protractor for the alidade. As a result of experience, however, it was found desirable to greatly modify this technique and to employ a specialized instrument. Excellent visible-area maps can be developed from the pictures but it was found for the California region that the application of the method is somewhat limited. A description of the technique developed and a brief discussion of the value of the method where phototransit pictures are already available are contained in the Appendix (p. 50).

RELIEF-MODEL METHOD

This method of constructing visible-area maps requires an accurate relief model of the unit, preferably of a scale of 1 inch to the mile or larger, which in itself involves a large amount of painstaking work and much expense. A single model on a 1-inch horizontal scale representing an area 60 miles square costs approximately $1,500; and this is a conservative estimate of the necessary initial investment if visible areas are determined by this means.

Further, the transferring of visible areas to a base map by the relief-model method is likely to result in inaccuracies. For this reason it is necessary to check carefully all such visible-area maps in the field before full reliance is placed on their dependability. This necessity for checking the maps destroys to a large degree the feasibility of using the method. Where a relief model is available, however, it may be substituted admirably in the preliminary work of field reconnaissance, saving much time and expense in "weeding out" ineffective points and locating promising ones. This preliminary reconnaissance and two ways of recording seen areas from relief models are described in the Appendix (p. 51).

METHODS OF FINAL SELECTION OF LOOKOUTS FOR THE DETECTION SYSTEM

As soon as the completed maps are received at the central office where the compilation will be handled, the pencil outlines of all visible areas are permanently inked in. Next, a tracing on good-quality tracing paper is prepared for each map including only areas visible, which are shown by hachure of a distinctive color, slope, or spacing for each map, and orientation lines. For ease in filing, the maps and tracings are numbered serially and indexed.

PLANIMETER METHOD OF COMPUTING LOOKOUT EFFICIENCY

In the California Region, as a result of experimentation, the following method has become standard for setting up a lookout system. Each visible-area tracing in turn is placed over the fire-occurrence (risk) zone map and the visible areas falling in each zone are planimetered. These "visible fire-occurrence areas" are then weighted by the average number of fires per thousand acres actually occurring during the past 10-year period, the weights being distributed according to the fire-occurrence classes already defined. For example, class 5, having more than 10 fires per thousand acres, may be weighted by 12; class 4, having 5.1 to 10 fires, by 7; class 3, 3.1 to 5 fires, by 4; and class 2, 1.1 to 3.0 fires, by 2. Class 1, 0.8 to 1 fire per thousand acres, is thrown into the no-fire class and weighted by 0.25. The weights used, with the exception of the last, are determined for each zone map by calculating the total number of fires per thousand acres occurring within the respective zones. Those given above would not, therefore, apply to all areas. Weighting was considered desirable because of the broad classification used, and because of the variation found between forests.

The weighted areas are totaled and the total value is divided by 1,000 to obtain an index which represents the average number of fires that might have been seen in areas directly visible from the point during the past 10 years. This is used as an index of the value of the point. When all tracings have been planimetered in this manner, the point having the highest index is designated tentatively as lookout no. 1 in the system.

When lookout no. 1 has been selected, its tracing is placed over the fire-occurrence zone map in order to eliminate from further consideration all areas covered by it. Lookout no. 2 is now selected by the same process except that these portions of the visible area already covered must be replanimetered and deducted, since they should be given no weight in determining the choice for second position.

After the first few points are selected in this way, their visible areas involve most of the protection unit, and selection now takes the form of "chinking in" important holes in the coverage, as revealed in a composite tracing. Finally a point is reached where additional lookouts will contribute so little that their construction is questionable. For northern California, an arbitrary limit of 25,000 acres of weighted zone area was established as the smallest contribution which would justify the construction of a lookout. Such a marginal lookout would have, on the basis of risk zones, an opportunity of detecting two to three fires a year in areas blind to other planned lookouts. No special consideration is given to a lookout point because it has already been developed, but all are treated on the same basis, each point not already selected competing with all others for each successive place in the lookout system.

Table 1 illustrates the application of the principle of diminishing returns to detection planning. The first lookouts can be so selected that a large area of important occurrence zones will be covered, but, as successive lookouts are added, the additional visible areas grow less and less, until the index is too small to justify the expense of construction and maintenance of another lookout. In mountainous forest regions this condition is reached when about 60 to 70 percent of full detection coverage has been obtained.

The proportional risk areas covered by the final system within the same unit are also shown in table 1. Contributions by lookouts from adjoining units and from three lookout-fireman positions considerably increase the totals.

TABLE 1.—*Net area covered by risk zones seen by first seven lookouts and other points in final detection system, Sierra National Forest* [1]

Lookouts, in order of selection	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	Index [2]
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	
Big Shuteye	90,406	22,854	2,822	1,286	--------	117,368	90.5
Goat Mountain	45,964	2,048	6,323	4,403	544	59,282	76.0
Music Mountain	47,565	7,738	3,162	3,123	262	61,850	64.4
Miami Mountain	33,638	1,011	2,106	4,019	1,062	41,836	58.0
Bald Mountain	33,197	4,883	1,677	1,382	--------	41,139	34.3
Mount Tom	60,563	6,790	90	--------	--------	67,443	29.9
Signal Peak	28,416	3,104	1,350	864	301	34,035	28.3
3 lookout-fireman locations	95,796	6,451	2,951	1,260	--------	106,458	57.4
13 contributing secondary points	81,644	9,083	2,151	1,518	589	94,985	65.1
Total area visible	517,189	63,962	22,632	17,855	2,758	624,396	--------
Total area of forest	848,700	123,936	33,261	32,314	3,533	1,041,744	--------
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Area visible	60.9	51.6	68.0	55.3	78.1	59.9	

[1] Net seen area is that seen independently of any lookout previously selected.

[2] The index is formed by dividing the total weighted risk-zone areas by 1,000 and is the probable number of fires which will be detected in net areas visible in 10 years. The risk weighting used against acreage in this case was as follows: Zone 1, 0.25; 2, 2.12; 3, 3.89; 4, 6.60; 5, 12.00.

Figure 11 illustrates graphically the principle of diminishing returns as applied to detection planning. It demonstrates also the added efficiency obtainable with careful planning procedure. Under the old system of nine lookouts, 225 fires were directly visible during a period of 10 years. If the first nine lookouts of the planned system had been in use, a total of 300 fires would have been directly visible at the same investment.

As a final check on the office compilation, it is well to make a tabulation of net seen areas, or all areas exclusively visible to each lookout. It is possible that a lookout accepted on the basis of value shown early in the compilation may have its original value reduced by the addition of several other lookouts until it will not show at the end an index value of 25; or a lookout considered the poorer of two closely competing points in the earlier set-up may be found to have the advantage.

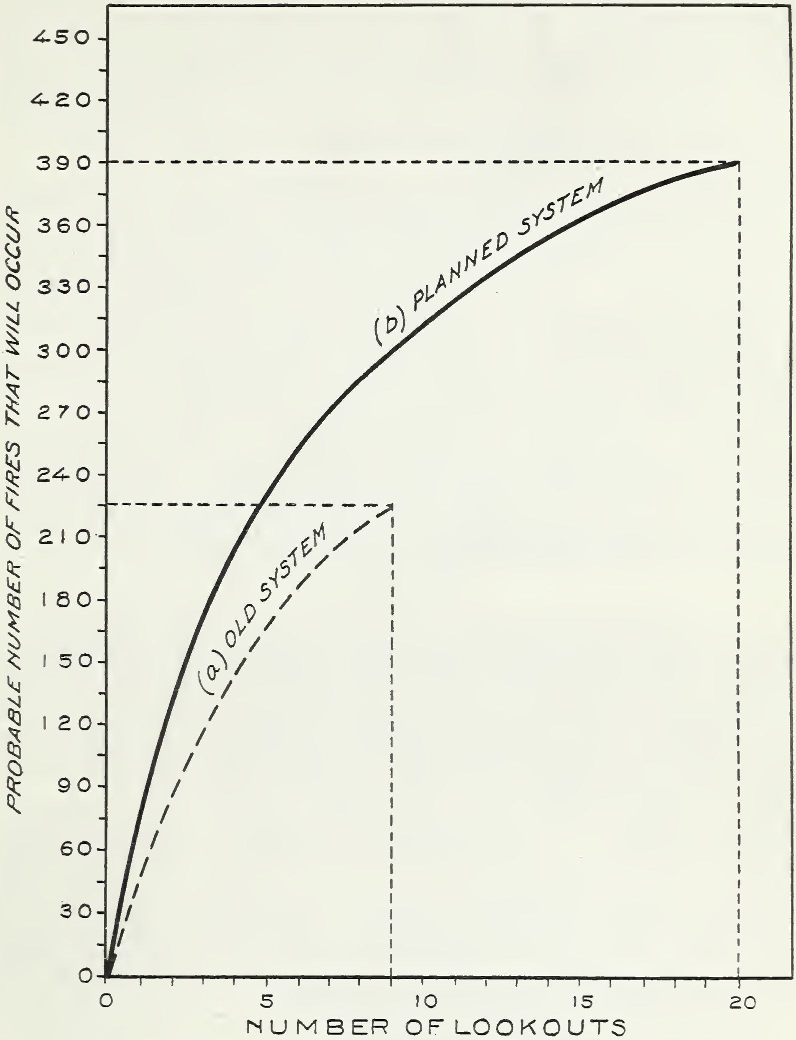

FIGURE 11.—Results obtained in planned detection on the Mendocino National Forest as compared to old system. If the first nine lookouts in the new system had been in use during the previous decade, a total of 300 fires would have been discovered in areas directly visible as compared to 225 fires under the old system. In addition to increasing the efficiency by careful selection, the planned system improved the detection by doubling the number of positions.

EVALUATING LOOKOUT COVERAGE BY PUNCH CARDS

Although the method described in the preceding discussion is simple, easily understood, and easily supervised, it is necessarily time-consuming, owing to the amount of planimetering and drafting work that must be undertaken for a careful analysis.

As a possible alternative, a study was made to test the adaptability of tabulating-machine methods to this type of work. A Hollerith tabulating machine, taking 80-column punch cards, was utilized for this purpose. A sample area of 130,000 acres in the southern end of the Sacramento Canyon unit of the Shasta National Forest was used as a means of testing out the method. The results showed considerable promise and the method was extended to the Mendocino and Cleveland Forests when these were included in the detection-planning program.

As a result of the work done by the machine-tabulating method, several advantages and disadvantages of treating area classifications in this way became apparent.

The advantages lie in the ease of combining and evaluating any measured factors for which a mathematical rating scheme can be used. The more complex the scheme, the greater the potential value of the method. In California, the simple rating scheme employed reduced this value, despite the usefulness of the machine tabulation in handling the complexity of possible lookout combinations. Perhaps the greatest merit of the overlay and planimeter method lies in its demonstration value, whereby each step is a graphic picture. Machine methods cannot supply any such step-by-step record. In planning for the forests handled by the machine it was found necessary to introduce to some extent the composite overlays, thus reducing the saving in drafting work achieved by the machine. In a large and complex planning project the use of machine facilities deserves study. Accordingly the trial application is treated in some detail in the Appendix for the illustrative value it may have (p. 52).

CONFERENCES

In the procedure followed in the California region, conferences at which the plan as developed in the office was subjected to the searching scrutiny of all members of the organization concerned with the administration of the unit were an integral part of the project. At these conferences the whole planning procedure was outlined and those unmeasured factors which had not previously entered into the planning, as cost, hazard, and value, were discussed.

Such conferences offer an opportunity also for the selection of additional points for supplementary lookouts or lookout-fireman stations. While primary lookouts must be justified solely on the basis of detection, lookout-fireman stations are justified when the movement of a fireman to a lookout point of secondary importance can be made without seriously affecting his contribution to speed of attack on fires. Many points which do not qualify as primary lookouts, may prove to be feasible lookout-fireman stations.

FINAL PLAN

After the conference has been held, and the number and location of lookouts decided, the final plan of detection development is prepared in final form for the supervisor's office. This consists chiefly of the maps, computations, and notes which led to the acceptance of the detection system as now approved and a final composite tracing of the accepted points showing the results. This composite shows by four colors on a topographic base map areas blind, areas visible to one lookout, areas visible to two lookouts, and areas visible to more than two lookouts, and the respective lookouts from which each area is visible are indicated by number. A copy of this is adapted for dispatcher use. A memorandum of the conclusions of the conference, the priorities of development, and summary tables such as already described complete the essential data.

In addition, the complete record, consisting of the visible-area maps and tracings made for all the points included in the study and a complete file of the corresponding field notes, is indexed and put in final reference form so that it will be readily available for any future revisions needed.

THE LOOKOUT STRUCTURE AND FACILITIES

When plans have established the identity of valuable lookout points, the best site on them, the tower height needed, and the obstructions to be removed to insure effective detection coverage, the lookout structure becomes the next important provision for converting the potential detection value into service.

The lookout house is probably the most distinctive structure used in forest-fire control. It now represents the product of 20 years of evolution and reflects many features that have become standard through long experience by the Forest Service. The details of design vary and are still in process of change, but the main features now conform closely to the essentials of a common design.

The requirements of design of a lookout structure may be classified under three headings of purposes to be met.

1. Maximum unobstructed view from inside the house.
2. Combined living and working quarters for most continuous and dependable detection service.
3. Comfort, convenience, and protection for the observer.

The success in meeting these requirements often determines the success of the whole detection investment, since the peculiar exactions of the job must be adapted to performance by a normal individual.

The manner in which these requirements are met in modern types of lookout houses is briefly described and illustrated. Detailed plans and specifications are available through regional foresters' offices. Three adaptations of the structure itself are in use based on the height required for observation. These are:

1. Combined observatory and living quarters built on the ground (fig. 12).
2. Combined observatory and living quarters built on towers of not exceeding 30 feet height. These low towers are often enclosed to provide storage or garage space (fig. 13).
3. Lookout towers carrying a 7- by 7-foot observatory independent of living quarters, reaching maximum heights of 120 feet (fig.14).

In addition, facilities for detection are at times combined with other structures where other purposes are to be served and where quarters for more than one man are necessary. The combined lookout-fireman house and the lookout-crew quarters buildings of recent design in this region represent such adaptations.

STANDARD LOOKOUT HOUSE

The combination of observatory and living quarters represents the standard design in this region. Its general structural features and plan of interior arrangement are illustrated by the side elevation drawing and the floor-plan drawing in figures 15 and 16. The completed structures are shown in figures 12 and 13. Some of the important features of this design, taken from the California National Forest Region building plans for lookout construction in 1935, are as follows:

Square frame building 14 by 14 feet, of central design, alined with the cardinal directions.

Plate glass in door and windows on all sides, permitting clear vision from any angle regardless of the sun's azimuth. Minimum obstruction to the view by corner posts and window frames, 8 inches in the design illustrated. Wide panes, 47 inches in vertical dimension, begin 28½ inches from floor. The lower edge of each pane is set out 1 inch from plumb, thereby reducing undesirable reflections.

A catwalk with a guardrail permitting access entirely around the structure for outside observations, to permit frequent window washing, and to reduce effect of confinement on the observer.

Metal-covered tight shutters permitting complete protection of windows when structure is unoccupied and, open, functioning as awnings securely braced in position by adjustable wooden braces or fastened by wing nuts to extensions of the rafters (figs. 13 and 15). These heavy shutters when braced in position are not affected by the wind and prevent excessive glare from the sun and excessive heat inside from direct rays on the glass.

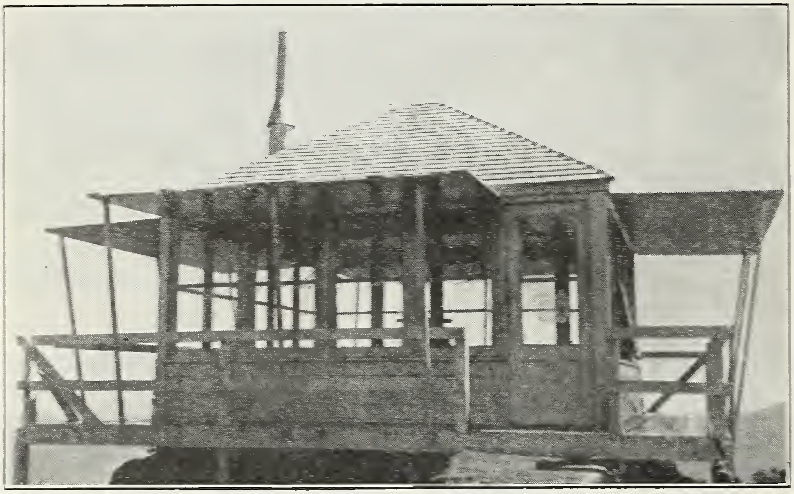

FIGURE 12.—Observatory set on ground at Herd Hill Lookout, Shasta National Forest.

Four-panel hip roof shingled.

Foundations and bracing built to withstand unusual wind stresses and frost conditions.

Complete lightning protection with special grounding of all metal furnishings and accessories designed to carry off heavy voltage safely. Experience has demonstrated the unusual lightning hazard to which the structure and observer are otherwise exposed. See diagram illustrating standard method which is result of study by experts.

Interior painted in neutral low-reflection finish restful to the eye.

Built-in cabinets and careful planning of arrangement of furnishings, working equipment, and accessories to permit efficient use of space, neatness in appearance, and convenience to the observer (fig. 16).

In recent construction each house is purchased ready cut and framed, with all miscellaneous hardware, etc., in correct amounts. The carpenter work is thus considerably reduced. Present costs of material are about $450, but vary considerably. The average con-

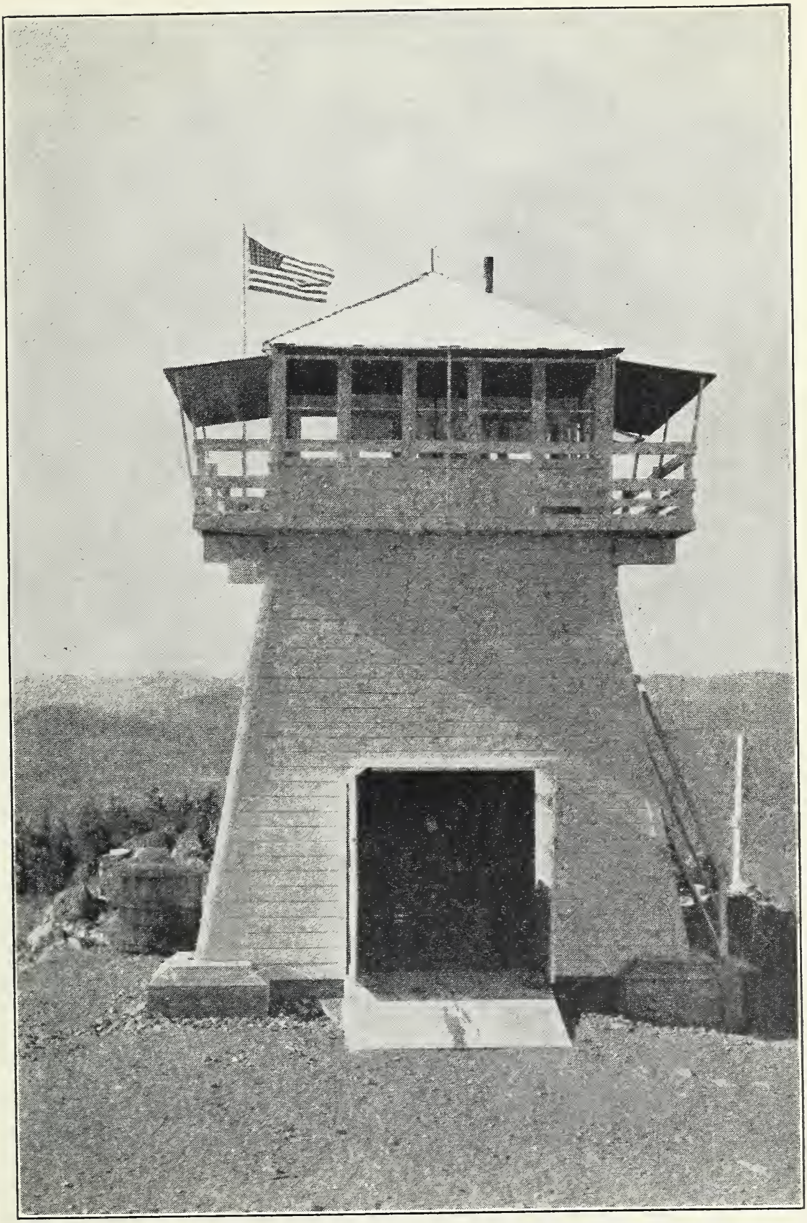

FIGURE 13.—Observatory on 20-foot tower, enclosed for garage and storage space; 1933-34 construction, Shasta National Forest.

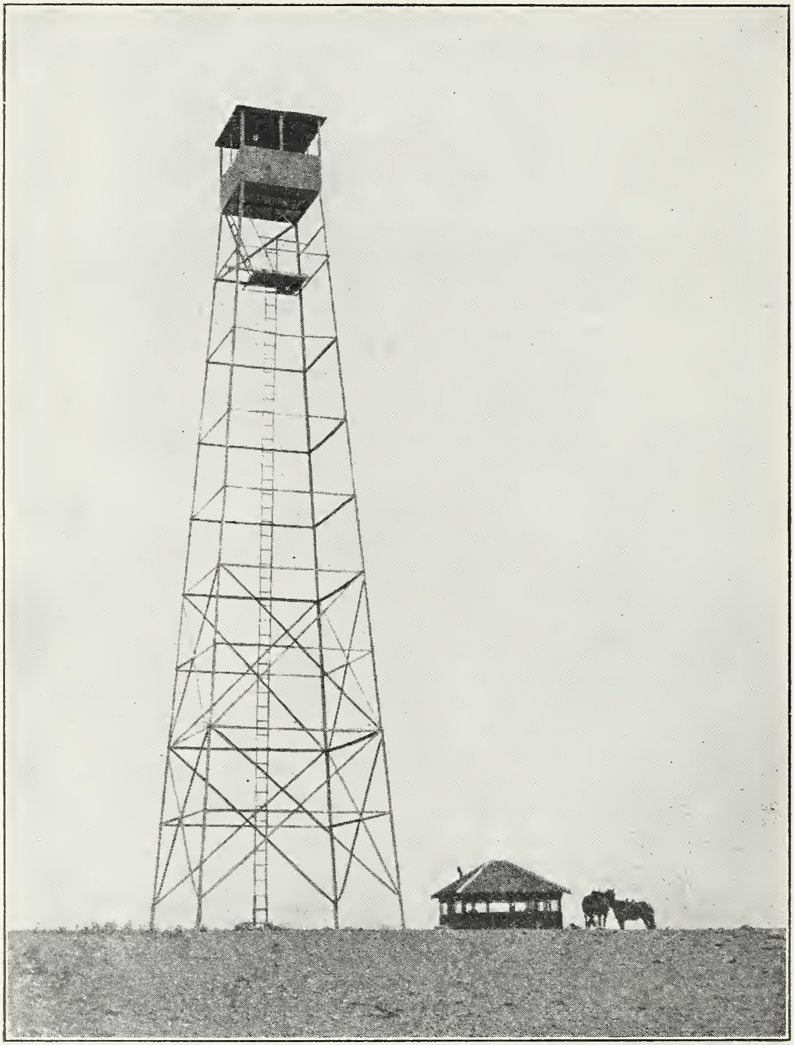

FIGURE 14.—High tower and dwelling at Santiago Peak Lookout, Cleveland National Forest.

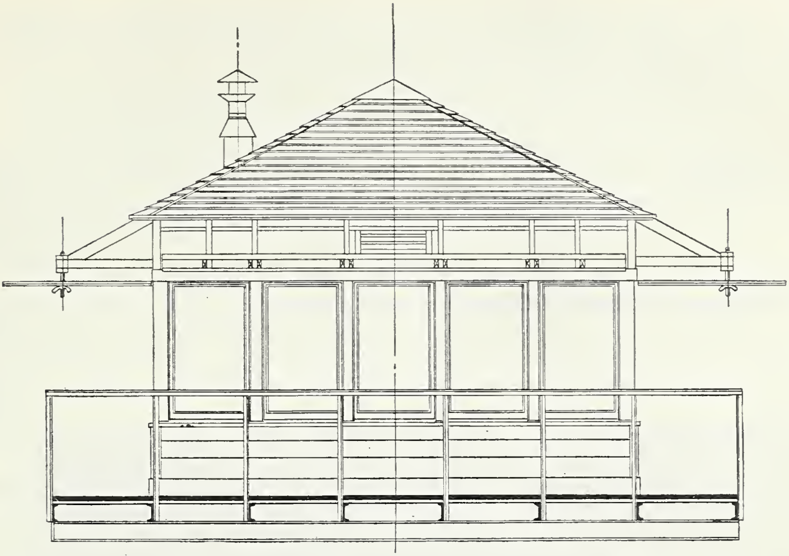

FIGURE 15.—Side elevation of standard combined observation and living quarters for lookout.

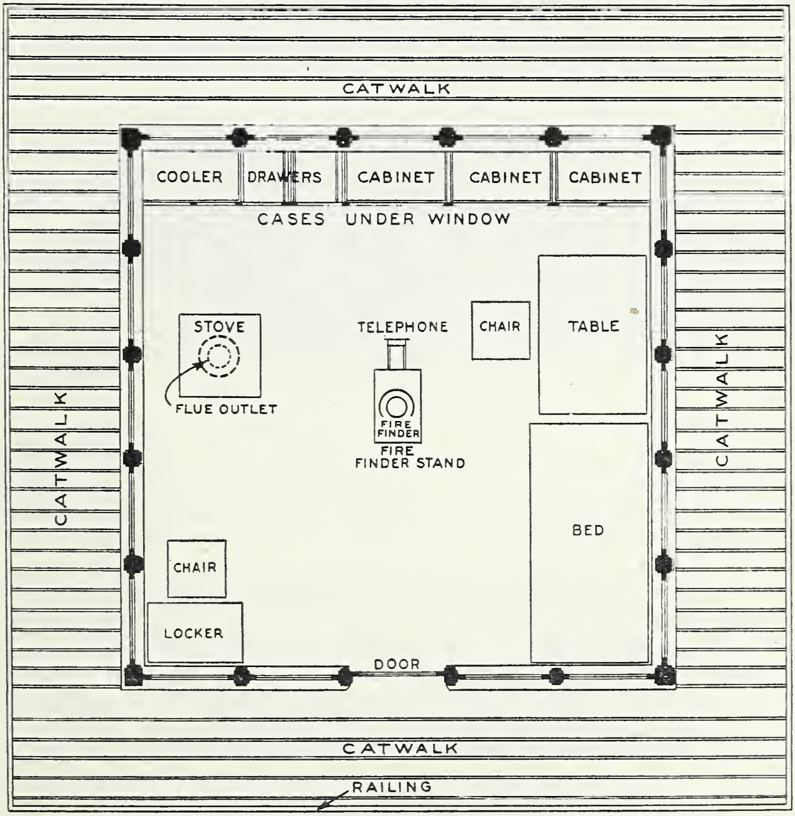

FIGURE 16.—Floor plan of standard 14- by 14-foot lookout house.

struction costs complete are about as follows for these three types of structure, based on 1931 costs. Material costs in 1935 were slightly higher but labor costs were in many cases lower.

STANDARD REGION 5 LOOKOUT HOUSE WITHOUT TOWER

Foundation:	
Material	$125
Labor	130
	255
Superstructure:	
Materials, including lightning protection	515
Labor	400
	915
Transportation—trucking 20 miles, packing 3 miles	300
Equipment	125
Water storage	75
	200
Total	1,670

Placing this structure on a 30-foot steel tower adds approximately $1,000 to the cost under the same conditions. On a wooden tower the additional cost varies widely but averages about the same.

An 80-foot steel tower with "crow's nest" and inside stairway costs approximately $1,960 to erect, with $1,000 used as the f. o. b. cost of steel.

The floor plan shows the arrangement of the housekeeping facilities essential to the job. All are designed to avoid undue projection above the window sills. The cabinets and cooler built in below the window level as a feature of the structure provide storage for food, kitchen equipment, and clothing. The stove, bed, table, and chairs complete these facilities. The floor is covered with a special composition linoleum.

WORKING EQUIPMENT

The essential items of working equipment are fire finder, maps, telephone, binoculars, weather instruments, forms, and place to put them.

THE FIRE FINDER OR LOOKOUT ALIDADE AND MAP BOARD

The essential requirement of a map correctly oriented with the surrounding country and provided with an alidade and azimuth circle to give azimuth readings of any point in the landscape has taken many forms and has evolved from crude beginnings, as has the lookout structure.

In the California Region a central raised platform carrying a high fixed table and a swivel chair to give the maximum view from a central working position were for a long period standard accessories. On this table a floating map board was used. It was oriented on the table by means of four strips of the same thickness as the map board firmly attached to the table to form a perfect square larger than the board. The table itself was adjusted to place this hollow square in orientation with the cardinal directions, then nailed in place. The guide strips preserved orientation of the map board when moved to avoid corner posts or other obstructions in sighting for azimuth.

In use, this arrangement had many objections and it was found difficult to preserve orientation of the strips because of warping. To meet difficulties in maintaining orientation with movement of the map, a steel-arm movable board was developed. With four 6-inch pivoted arms properly machined, this board permits parallel movement of the map to a maximum of 12 inches. This type of board is adapted to a table-top mounting. The principle may have further adaptations in providing movement of the map. To economize space a high stool has been substituted for the part of the platform carrying the rotating chair.

In more recent construction, the compact and convenient fire finders designed in one piece have been adopted as standard equipment. Both the Osborne and Bosworth fire finders are now in use in the California Region. In these fire finders the lookout map is mounted on a circular disk with a rim graduated to azimuth. The alidade consists of two sights mounted to rotate about the disk. The line of sight on the map is preserved by a taut wire or tape stretched between them.

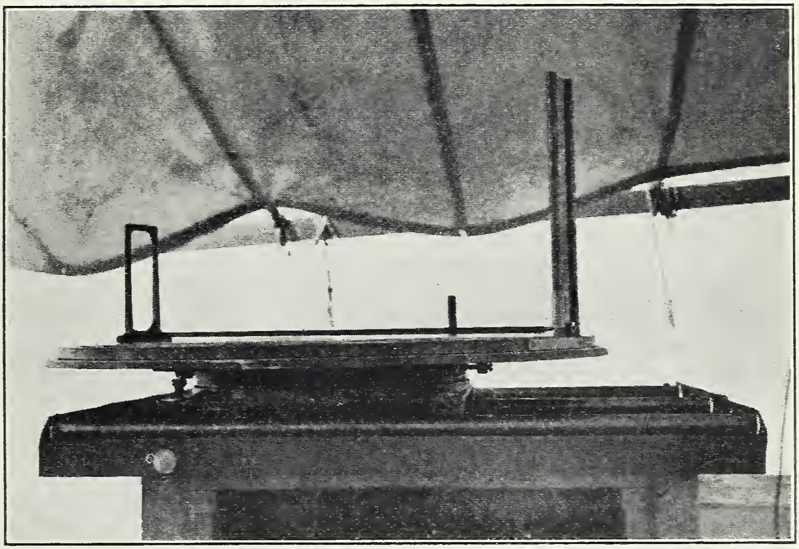

FIGURE 17.—Osborne fire finder installed for lookout use. A stand with accommodation for telephone and report forms has been designed for use on California forests.

The Osborne fire finder, designed by Osborne of the Pacific Northwest National Forest Region, provides for exact leveling of the instrument and for obtaining vertical-angle measurements as well as azimuth in locating fires (fig. 17). Complete details of adjustment and operation of this instrument are available in a booklet prepared by Osborne.[4] Vertical-angle readings are of most value where lack of definite landmarks, a continuous timber canopy, and lack of cross readings by a second lookout must be contended with in locating fires. In the California Region they have been less used than in the Northwest, but in a few localities are of useful reference in the use of the phototransit pictures.

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[4] OSBORNE, W. B. THE LOOKOUT SYSTEM. *In* Western Forestry and Conservation Association, Western Fire Fighters' Manual, ed. 6, ch. 5. 1934. Seattle.

The Bosworth fire finder, developed in the Northern Rocky Mountain National Forest Region has similar advantages in convenience and compactness with the Osborne, but is of simpler construction and does not carry any provision for vertical-angle measurement. It has the advantage of being combined with a metal base, requiring no mounting (fig. 18).

In service in California both these instruments have proved satisfactory. A stand has been designed for mounting the Osborne fire finder which also provides a neat and convenient space for the telephone and shelf space for lookout forms. For use with the Bosworth fire finder, a simple pendulum vertical-angle reader has been developed which is independent of leveling. This will permit use of vertical angles if needed in connection with the phototransit pictures that are gradually being made available for all approved lookouts on the California forests.

The two instruments are of comparable cost in recent purchases, but the requirement of a fire-finder support or stand for the Osborne must be added to its cost.

THE LOOKOUT MAP

The degree of accuracy in the lookout's map is a very important element in his ability to give correct information to the fire dispatcher. The inaccuracy of many of the old base maps has given rise to the common preference of field men for lookouts who know their territory intimately from a long period of residence. As desirable as this qualification may be in a lookout, it should not overshadow other more important qualifications essential to dependable performance. Normally, the map mounted on the fire-finder disk or lookout map board, should be of ½-inch scale and should preferably be on a topographic base. Where the lookout coverage is relatively small, an inch-scale base map may be substituted. In either case, supplementary maps which give the relationship of the country seen by the observer to the whole protection unit should always be on hand for convenient reference. This may be accomplished in several ways and it is sometimes found desirable to furnish the lookout with a complete forest map with printed azimuth circles for each of his neighboring lookouts. This aids him considerably in developing familiarity with nearby territory blind to him but visible to another. It is particularly helpful where there is easy communication between adjoining observers.

The lookout map should be mounted at headquarters. The first important precaution in mounting a lookout map is that of obtaining the exact location on the map of the lookout station. This should be obtained through accurate triangulation from permanent control points, with little dependence given to section-corner ties or to apparent relationships on the topographic map, unless the lookout point itself is also a triangulation point. When this exact location has been pricked through the map, the map is cut to the correct size for mounting.

In the mounting, several precautions must be taken to insure a smooth mount and to avoid distortion or stretching of the map. Shellac seems to be the best mounting base. Some of the most successful mounts have been obtained by first coating the back of the map with shellac, permitting the shellac to set for only a few seconds,

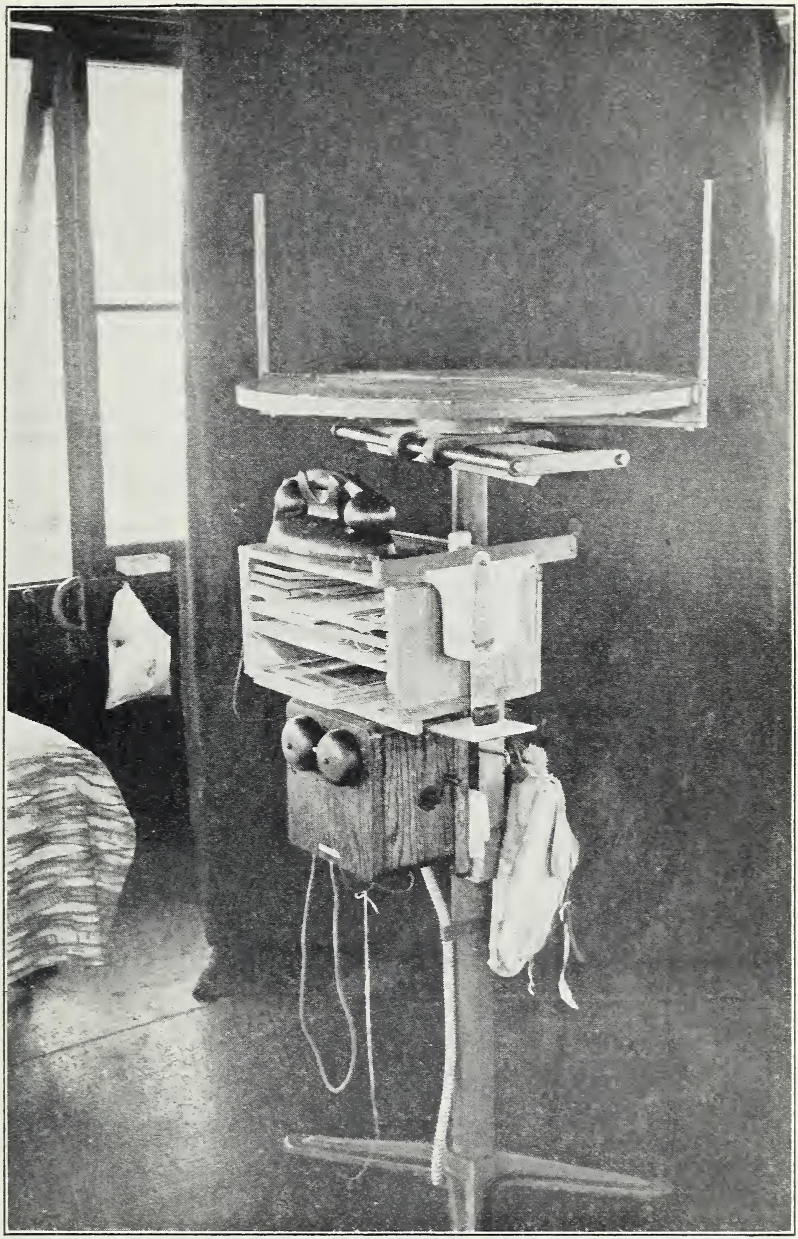

FIGURE 18.—The Bosworth fire finder has its own metal base. It does not include any provision for vertical-angle measurement, but this can be supplied, when phototransit pictures are used, in the simple pendulum form.

then carefully touching the center of the map to the disk or board in place and gradually allowing the outer edges to settle down by their own weight, but without smoothing the map out by the hands. Before the shellac has actually set, the map is again carefully pulled up from the edges, and beginning at the center is brought in full contact with the mounting surface and smoothed progressively toward the edges. With a little experience it was found that a perfect mounting without wrinkles or blisters in the map could be obtained in this way. If a poor mount is obtained, it is much better to make a new mount than to run the risk of distorting the map by pricking blisters, cutting the wrinkles or by other means. When a good mount has been obtained, the surface of the map should be given a complete coat of shellac and allowed to dry. A final coat of clear spar varnish will protect the surface for a long period of use. Care should be taken to keep varnish or any other preparation with an oil base from contact with either surface of the map lest it make transparent spots or discolorations. In California a new commercial preparation in the nature of a cellophane solution has also been used very successfully. This gives a smooth, elastic surface which will not crack and which may be marked with pencil or pen and easily washed clean again.

THE TELEPHONE

Communication to the lookout observer is vital to his function and often represents his only link to his organization for long periods. Normally, the telephone fulfills this function and is a much-used tool.

Assuming that a good telephone circuit is maintained and a proper installation is made, the form of the instrument and its adaptability to the current job is of next importance. With many of the other items of equipment, the telephone, too, has been considerably improved in its adaptability to the work. The instrument now adopted as standard in this region is of the improved French or "grabaphone" type, and is installed conveniently on the stand or base supporting the central fire finder. The combination transmitter and receiver gives the observer considerable freedom in making notes or in writing down information when he is talking. A further provision is that of a long cord which permits the observer to move around the room and check for a reported smoke or for other information that may be requested, without the necessity of leaving his telephone.

RADIO

With the development of successful types of portable radio, many lookouts will be called on to operate these instruments either in emergencies or under certain conditions as a part of the regular fire-control communication system. The conditions under which the lookout point can function best in this way are (1) when it is desired to obtain detection service for short periods from inaccessible emergency-lookout points, or (2) when, for any reason, regular telephone communication is difficult or lacking. In such cases, an effective way to include the emergency point in the communication system is to install radio communication between such a point and a convenient neighboring lookout who is on the telephone network. Another service which radio may perform effectively is to connect with the lookout any fire crew or individual fireman going into inaccessible country. By means of high-frequency sets complete and dependable contact can be maintained in this way within all of the territory seen by the lookout, and it then becomes possible to report to the dispatcher the exact progress of events on the ground so that reinforcements can be provided without delay or inefficiency. With future progress in development of high-frequency radio communication, it is probable that lookout stations may serve still further as the eyes of the fire organization.

BINOCULARS

In the past there has been considerable difference of opinion as to the value of binoculars as a part of standard lookout equipment. This difference is traceable mostly to the use of improper instruments or to a misconception of the part that binoculars should play in the lookout job. Experience has demonstrated that the value of binoculars is not that of substituting for the naked eye in regular observations of all the territory, but rather that of furnishing a good tool to supplement the eye whenever there is need of examining any particular location in detail. That is, if in regular observation there is any suspicion of a smoke, use of the binoculars will usually settle the question and permit either a more prompt discovery or the avoidance of a false alarm. In localized high-risk areas near to a lookout, it is often possible with the aid of binoculars to check on the activities of forest users or traveling parties and to report small fires or incipient fires that would otherwise await discovery until the following day.

It is important that binoculars be of the proper magnification for effective use. Investigation has demonstrated that a magnification of from 6 to 7 diameters is most practical for detection purposes. Greater magnification restricts the view and gives an unsteady image when used without mechanical support. In brief, the specifications that have been found preferable within this range of magnification in prismatic binoculars are that the objective lens should be large enough to provide an exit pupil of 5 millimeters, objectives widely spaced, good definition, wide field, and interocular and individual eyepiece focusing adjustments. To avoid the possibility of hidden defects and poor adjustments, purchase from dependable firms is important.

For a small fee, binoculars will be critically examined by the United States Bureau of Standards. Before any large purchases are made, or a particular model is standardized, advantage may well be taken of this service to determine the quality in a more detailed manner than would otherwise be possible.

WEATHER INSTRUMENTS

Meteorological data are needed for many purposes in connection with fire control. Currently, such information is used by the lookout and protection forces in judging size of fire, rate of spread, and action to be taken. The Weather Bureau depends on the observations from a good many peaks for building its daily weather map and in forecasting fire-weather conditions. It is, therefore, essential that the lookout have the ability to read a thermometer, operate and read a psychrometer, and read an anemometer. This full equipment is standard only on selected peaks, but all should be furnished with a thermometer and psychrometer.

FORMS

A place must be provided for keeping forms to record data required of each lookout. These consist, in California, of:

1. Reporting form on individual fires.
2. Climatological data.
3. Reports on lightning storms.
4. Visibility study.

In the standard lookout house, as already described, the stand designed for the fire finder accommodates the necessary forms.

COLORED GLASSES

Colored glasses are of considerable value to an observer in preventing eye strain when he is observing a brightly lighted landscape or must look into the sun. Investigation of types best adapted to the purpose has shown that relief from eye strain is the only value of such glasses. For this purpose, shielding of the eye from the ultraviolet light rays is about all that is necessary. Ordinary lenses do this quite effectively. It has been found, however, that most of the cheap colored glasses are distorted to some degree and are apt to contribute to eye strain in long use. For this reason it is much better to use protective glasses with ground lenses which are known to be optically correct. Amber or green lenses are often used. McArdle, as a result of observations made while with the Pacific Northwest Forest Experiment Station, recommends a dark neutral-colored optical glass for observations toward the sun.

WATER SUPPLY

If the lookout is to live on the peak, provision must be made to supply sufficient water for domestic use and reasonable daily quantities of drinking water.

Each peak presents a problem in itself in regard to water supply. For drinking water, the best plan is to utilize existing springs near the peak, even if considerable expenditures are necessary to develop them. Even a very meager spring can furnish the 3 gallons or so of water a day that the average lookout requires, removing the necessity for outside service. Springs must be within 1 hour's round trip distance; with one daily trip, loss of detection service can be reduced to a minimum, particularly if the trips are made in the early morning hours. Requiring lookouts to travel more than 1 hour for drinking water involves a sacrifice of too much valuable time and in such cases other means for supplying his needs must be found. High peaks frequently are covered with snowbanks which persist through the fire season. These have been used successfully as a source of drinking water.

It is rather the unusual lookout station that has an available spring or running stream with a sufficient supply of drinking and domestic water. In the early days, lack of water supply was justification for having the lookout live at some point below the peak or observatory, travelling daily to and from work. This in practice meant an excessive loss of travel time which should have been devoted to detection service and practically no service during the evening, night, or early-morning hours. The next development, as a remedy of this situation, was the periodic delivery of water to the lookout.

This is the least desirable method, since it is not only costly but uncertain and ties up men in the protection organization who have other important duties to perform. If there is no escape from it, however, by far the best way is to maintain adequate storage facilities with occasional delivery by tank truck.

An excellent provision for solving this problem on many peaks is the utilization of rain water. The water is collected by means of rain gutters on the lookout house and is stored in a 500-gallon galvanized-iron tank beneath the lookout house. The old style chain-and-bucket pump is then used to convey the water from storage to the house, being preferred because of the aeration which the water receives from the descending buckets. Such a water collection and storage system has served satisfactorily even in a region of low annual rainfall, and is regarded as an adequate solution to the water problem for lookouts in semiarid regions. In regions, however, where heavy snow and sleet storms are common in the winter, damage may be caused to the gutters and drain pipes.

THE LOOKOUT MAN

All the foregoing plans, provisions, and costs directed toward an efficient detection system and hence toward more successful fire control, focus directly toward and depend upon the performance of the lookout observer. For this reason, detection is a service subject to the usual human failures, when even the best of facilities are provided, and it is important that careful attention be given to the observer as a fallible individual placed in this key position.

The gap between actual possibilities for prompt detection of fires and the recorded average performance of any group of lookouts is a wide one. Leaving out of consideration the delays possibly attributable to failure of smoke to rise above trees and bad visibility due to smoke or haze or the position of the sun, there still remain a considerable but undetermined number of fires with seriously delayed discovery of which the only possible diagnosis is human failure. That this gap exists is shown not only by average recorded performance, but also by day-to-day administrative experience over many years. How often has a dispatcher receiving report of a fire in an area visible to some lookout, called the lookout, asked him to look in that particular area, and been informed that smoke is just showing up! In the vast majority of these invitational discoveries, the lookout man should have detected the smoke without having it called to his attention. Some of these failures are clearly chargeable to the lookout man himself. But probably more are due to the men who selected him for the job in the first place and who are responsible for training him and inspecting and checking him. Failure of a lookout man to render acceptable service because of defective eyesight or lack of training is common enough, but is not fairly chargeable to him.

The lookout job is one of highly specialized, exacting service, performed under abnormal and trying conditions, requiring definite and known qualities and abilities. To obtain the maximum service from lookouts, the individuals must be selected, trained, and equipped from the standpoint of definite requirements, conditions, and limitations inherent in the job. The following analysis attempts to set down what these are.

The services required of a lookout man may be summarized as follows:

A. Detection of fire:
  1. Recognition of smoke.
  2. Location of fire on map by azimuth, distance, and by legal subdivision.
  3. Relation of fire location to natural features in the locality.
  4. Description of size, character of fire, and apparent rate of spread at moment of observation.
  5. Distinction between man-caused and lightning fires.
  6. Determination of whether point of origin is in blind or visible area.
B. Progress of fire:
  1. Information on rate and direction of spread and areas into which it is spreading.
  2. Report on parts of fire which have ceased to spread.
C. Weather reports:
  1. Regular daily reports as prescribed in fire plan.
  2. Special reports on going fires.
D. Emergency repairs of communication system at or near the station.

.Physical and mental qualifications in the lookout man, as demanded by the job, are:

A. Inherent qualities of the lookout man for particular requirements of the job:
  1. Good eyesight.
  2. Physical ability to live and work at the required elevation without unusual rest periods; this excludes chronic sickness or organic troubles.
  3. Ability to live alone for long periods without worry.
  4. Capacity to do the job continuously, without frequent outside stimulus or supervision.
  5. Contentment with the job, which gives little opportunity for physical exertion or for a change of scene.
  6. Ability to describe what he sees.
B. Required aptitudes, experience, and knowledge:
  1. Ability to cook for himself and to take care of himself.
  2. Ability to use the instruments of the job—the fire finder, telephone, map, weather instruments.
  3. Ability to record simple notes and quantitative observation on required forms.
  4. Ability to identify map with topography.
  5. Ability to name topographic and cultural features.
  6. Ability to recognize major classes of cover—virgin forests, cut-over lands, and second growth, brush, grass, barren.
  7. Ability to distinguish reportable smokes from smokes arising from towns, mills, railroads, etc., and from pseudo-fires such as dust clouds, gray rocks, scars on hillsides.
  8. Knowledge of fires—ability to judge:
    (*a*) Size of fire at a given moment.
    (*b*) Material burning, as judged by color and character of smoke.
    (*c*) Rate of spread, as judged by angle, volume, and movement of smoke.
    (*d*) Whether ground, surface, or crown fire.
    (*e*) When fire has ceased to spread or is controlled.

SELECTION OF LOOKOUT MAN

FUNDAMENTAL DETAILS IN PROCESS OF SELECTION

Assuming the correctness of the above list of needed qualifications, the next problem is to determine which can be definitely tested before hiring and what are the most effective means of making the tests.

1. Eyesight can be determined by appropriate eyesight tests administered by oculists. Often correct fitting with glasses will take care of defects of vision. In addition, a specialized eyesight test has been designed which goes further than the assurance of normal eyesight. This has shown considerable promise.

2. Physical ability to live on the job, and presence or absence of serious organic defects—by appropriate medical examination by a physician.

3. Ability to take care of himself and cook—by simple tests at any Forest Service station.
4. Ability to live alone, etc. This can usually be judged from a man's previous occupations and his own opinions, or by modern personality test.
5. Capacity to do the job continuously without frequent outside stimulus. This can be judged from individual's previous history, particularly if he performed creditably on small jobs such as one- or two-man trail maintenance.
6. Contentment with a job, with little change of scenery, and with little required physical exertion. Previous satisfaction with jobs such as caretaker or guard jobs at isolated stations will often give a clue to this quality. More often it will be necessary to test this quality on the job itself.
7. Ability to describe what he sees. This can be tested from a suitable point in the field.

There is another group of qualities designated as "knowledge of job", on which previously inexperienced men can be given instruction and training during the usual 3-day training period.

After this training, the individuals failing to pass an examination designed to show aptitude for learning should be eliminated from further consideration. Men who do pass will, with normal instruction from the district ranger, be able to perform their required jobs.

Only long-time experience and systematic training on the job can develop the ability to size up going fires and describe what they are doing.

The selection of a group of lookouts for a national forest thus involves the following fundamental steps in the following order:

1. Elimination of applicants failing to pass the eyesight and physical examinations.
2. Elimination of individuals whose personal histories or specific tests indicated deficiencies in ability to live alone, capacity to work without supervision, and contentment with the lookout job.
3. Individuals surviving these eliminations would then be given intensive training in the rudiments of the job, followed by an examination in these subjects. A further elimination leaves a group ready for assignment and for intensive instruction on the job.

USE OF PSYCHOLOGICAL TESTS IN SELECTING LOOKOUTS

Psychologists have developed a number of definite testing devices, designed to supplement or replace other forms of examinations in such problems as admission of students to universities, fitting of the man to the job in industry, and selection of individuals for special training or advancement. The tests having potential value and significance in the problem of selecting lookouts are the intelligence test, the aptitude test, and the personality test. None of the known tests have been worked out with attention to the lookout job, nor have they been extensively applied to groups of lookout men to determine their applicability.

Of these tests, the most generally known is the "intelligence test" (of which there are many), leading to an i. q. (intelligence quotient) rating. One well-established test is the Stanford-Binet which when applied to typical groups of guards and lookouts showed individuals ranging from exceedingly low to very high ratings. Probably there is some dead line in this test, below which men should not be hired. Testing of a sufficient number of lookouts, and comparison of their intelligence test ratings with the regular administrative ratings of their ability by their immediate superiors, would soon answer the question whether such tests have a place in the selection of lookouts or of other short-term employees in the fire-control organization and, if so, what dead lines in rating should be established. It has been noticeable in the small-scale tests made, that men receiving very low ratings are usually defended by their superiors on the basis of their long experience in the mountains, their knowledge of the country, or their willingness to accept uncomplainingly the disagreeable features of the lookout job.

The aptitude tests are designed primarily for guidance of students entering college, and for employees entering industry, or for men already employed, but who are apparently square pegs in round holes, and who should be shifted to a different kind of job. Here again, although their usefulness in selection of lookouts is an unknown quantity, the tests deserve a trial, simply as one possible means of judging the man for the job.

The personality test perhaps offers a real chance for determining and weighing the elusive personal characteristics which cannot be judged by seeing the man, giving him a physical examination, or even by interviewing him and studying his previous history. It is designed to pick out individuals toward both ends of the human spectrum—those who are unhappy if dependent upon themselves, and those who are unhappy unless left by themselves. If the test can do this, it is a valuable tool, in conjunction with study of the individual's history, in the preliminary selection of candidates for the lookout job. Systematic testing of men who have succeeded and failed at the job because of personality would answer the question.

After all, the lookout job is a peculiar one, in which only a very small percentage of men can find permanent satisfaction. The use of any device which will help pick out these men is thoroughly justified because of the enormous wastage in the trial-and-error method heretofore used.

The results of applying personality tests to a group of 80 lookouts by Paul P. Pitchlyn, chief personnel officer of the California Region, gave some surprising preliminary results. While the tests were insufficient evidence for detailed conclusions, they demonstrated clearly that the best lookouts were not of the so-called introvert type who prefer living to themselves, but represented qualities nearer to the extrovert end of the personality spectrum. The distribution of qualities of personality in the best lookout was about that to be expected in a group of college students. Such investigations aid in dispelling many traditional preconceptions that in the past have had undue influence on the selection of lookout observers.

GROUP TRAINING OF LOOKOUTS

Heretofore lookouts have usually been trained as part of the forest-guard group, with little specific attention given to the peculiar needs of the lookout job. As now handled, the lookouts are given instruction in a group, with particular emphasis on the following subjects:

1. Map reading, including understanding of the conventional symbols used on maps, and of the meaning of the sectional survey lines used on Forest Service maps, the significance and use of the azimuth circle on lookout maps.
2. Tying map to ground, locating selected natural features on the map.
3. Setting up and orienting the fire finder or lookout map, including tying in with key peaks.
4. Rapid reading and recording of azimuth to selected points. Avoidance of corner posts.
5. The obtaining of vertical angles. In the use of the Osborne fire finder and panoramic pictures, fire-finder leveling and the manual operation of the vertical-angle scale are important.

6. The scaling off and reporting of horizontal distances to selected points.

7. Demonstrations of just what constitutes a complete report by a lookout and how it is efficiently obtained and transmitted.

8. The use of the telephone, with precautions and repairs required of the lookout.

9. Use of instruments, including binoculars, weather instruments.

10. Instruction in display of flag, care of quarters, and requirements in personal appearance.

TRAINING OF LOOKOUTS ON THE JOB

In this discussion a modern physical plant and suitable working conditions are assumed. Effective training of lookouts on the job must be a continuous and a planned process carried out by the district ranger and the dispatcher. Even after systematic training for a full season with a green lookout, the process will return dividends if continued during subsequent seasons of employment.

The principal training opportunities are:

A. The initial installation of the lookout for the season's work. At this time the following tasks can be carried out:

1. Orienting and tying the map to major topographic and cultural features. This should ordinarily be confined to about 5 to 10 major points, leaving the filling in of detail for the lookout himself and for subsequent inspections. A common mistake is to overwhelm the lookout with minute details and place names so that he becomes confused and fails to absorb any of the information given him. It is preferable to give him a skeleton of major features, to which he can add detail.
2. Listing and showing both on the ground and on the map, checked by alidade reading, known smokes from legitimate fires and pseudo-smokes. Most peaks have only a few of these and the entire job can be done at one time.
3. Review of those points of the "fire plan" affecting conditions of service, care of station, and equipment.
4. Checking all supplies and equipment for completeness and serviceability.
5. Instruction in switching to obtain full use of communication system.
6. Instruction in art of observation.
7. Instruction in quick, accurate telephone etiquette to be used in telephoning reports of fires by azimuth and by topographic location, and additional information to be given dispatcher, including whether directly or indirectly visible, whether a spot or spreading fire, the kind of smoke, apparent wind and cover conditions at the fire, and what other detection agency should see the fire.
8. Use of records—including lookout fire report, weather records, and special forms for recording visibility conditions.

B. Daily contact with dispatcher:

1. Reports from dispatcher on new or changed false and legitimate smokes.
2. Checks on telephone line, presence of man on job, standard time, etc.
3. When a fire is reported by the lookout to the dispatcher, the latter, as soon as dispatching is completed, will have an opportunity to question the lookout regarding the features of the fire reported. These will include the kind of cover, size and kind of fire, character of smoke, whether seen directly or indirectly, etc. In this way the dispatcher will give significance to things seen by the lookout and will build up the qualitative information regarding fires besides mere azimuth and distance reading.

   In the case of long-continued fires, the dispatcher should report to the lookout any information from other sources that will be useful to the lookout in building up an interpretative knowledge of the fire and so make more valuable his subsequent reports.
4. When fires are over and the dispatcher has final reports from the suppression men regarding the exact location, size when reached, final area, and character of cover, these should be reported to the lookout to be checked by him against his own statements and judgments. This very important function should be handled systematically on the initiative of the dispatcher.

5. Fires shown on visible-area maps as within the direct visibility zone of the lookout, which he failed to detect within the specified time, will be immediately reported back by the dispatcher, to check both the map and the man.

6. False alarms reported as actual fires by the lookout will be reported back as such to the lookout by the dispatcher.

7. When weather reports from the lookout are out of line with reports from those from other nearby stations, the dispatcher will obtain repeat observations.

C. Inspection trips:

Recurrent inspection trips by rangers give opportunity to:

1. Determine by questioning the extent to which the lookout has acquired detailed knowledge of his territory and to correct and supplement this knowledge.
2. Provide him with a risk map and instruct him in the particular importance of close watching within those areas, including inspection of key points with binoculars.
3. Review in detail every fire in which the lookout has participated, checking azimuth, location, size, and character reported by the lookout. This affords an opportunity for clarifying misconceptions and doubts existing in the lookout's mind as to the job.
4. Check required written records and reports and the use of weather instruments.
5. Give special training in detection of lightning fires accomplished through recording azimuths of strikes and close watching of these azimuths for subsequent smoke; explain the importance of night watching for these fires and the commonly delayed appearance of smokes.
6. The district ranger must depend on the lookout for information on changes in visibility which necessitate supplemental detection. To accomplish this, a series of definite points should be selected by the district ranger and marked on the lookout map, against which the lookout shall systematically check visibility.

OVERCOMING OBSTACLES INHERENT IN THE JOB

Very few lookout men, in spite of training and supervision, deliver the full output of work actually possible. This arises from a number of difficulties under which the men must work; and these must be clearly stated before attempting to indicate how they may be overcome in whole or in part:

1. The strain of constant and unvarying attention to a familiar landscape results both in mental and eye fatigue, and is reflected in reduced efficiency toward the end of the day. Mere living at high elevation sets up strains in most men. The intense insolation, normally high winds, severe electrical storms of high elevations, all may contribute in some degree to physical distress and nervous tension.
2. Where considerable periods elapse without any fires, a subconscious feeling of disinterest is likely to develop and build up into an idea that nothing of consequence will happen. This, of course, results in carelessness and irregular inspection of his territory by the lookout.
3. The frequent occurrence of haze, smoke, and the necessity of looking into the sun increase the effort needed to do the job, and, consequently, the strain on the individual.
4. Living apart from other human beings represents an abnormal condition for most men and sets up dissatisfaction.
5. Modern research has shown that on jobs monotonous in nature and requiring constant attention, the average individual cannot maintain a reasonably constant level of effectiveness if the daily working period is above 7 or 8 hours. The essentially monotonous lookout job requires much longer hours of service than this.
6. Most individuals respond best under direct oversight and supervision and tend to slump when they are left to their own resources. The lookout man must work fully 95 percent of his time without direct supervision.
7. Interest in the job is certain to lag unless the individual can be given the idea that he is competing against other lookouts, his own maximum possibilities, or against inherent difficulties of the job. He has a natural proprietary interest in

fires which he discovers and will lose interest in the job unless this instinct is satisfied.

The net effect of all these difficulties is that the lookout tends to watch his country too irregularly, haphazardly, and casually. Practically, it means the average performance is at present only about 70 percent.

Deliberate and planned devices directed towards specific weaknesses are essential to raise this average of performance. Mere exhortation of the lookout man in the fire plan or in the course of periodic inspection will not avail. Four main sources of discontent, disability, or laxness to be considered are:

A. Physical comfort:

Protection against wind, sun glare, and temperature is largely obtained through correct design and construction of the lookout plant. Essential features to reduce glare are outside shutters used as awnings to break direct rays of sun, and dark-grey or green inside paint to minimize reflected light. Additional protection against glare can be secured with properly colored glasses. The physical comfort of the lookout is the first essential.

B. Feeling of safety:

Correct design of the plant includes railing around the outside platform, and complete wiring of the structure for lightning protection. These features of design will take care of the safety of the man and give him peace of mind in this regard. Temporary stations in trees and rocks require men who can adapt themselves to the hazardous conditions of service, but even here hazards can be minimized to some extent.

C. Convenient conditions for the job:

Convenience must be provided principally in the design of the plant. (See side elevation and floor plan drawings, figs. 15 and 16). Correct principles now in use include:

1. Low windows so that the man can see his territory when sitting down, and can obtain full view of his territory at the eye height of his alidade.
2. Windows on all sides with fair-sized panes of high-quality glass and with minimum distance between windows so that the man will not have to dodge obstructions to his vision.
3. Telephone, fire finder, and notebook within easy reach.
4. Combined living and working quarters permitting a close watch of his country while cooking, washing dishes, or resting at night.

D. Sustained interest and attention to job.

Ordinarily the lookout man is instructed that his job is to discover and report fires. The only occasion requiring definite action on his part is when a fire actually occurs and this may be only two or three times a season. For the California National Forest Region the average number of fires discovered by lookouts is only six per season. To obtain effective attention to his territory, it is necessary to substitute for fires something else which requires definite observation of his territory at specific times and the noting and reporting of observed facts. In other words, instead of the indeterminate responsibility arising only when a fire starts, he needs a recurrent responsibility tied to definite places and definite hours. Moreover, this task must be one intrinsically worth while and not an essentially trivial and useless device the purpose of which is obviously to cajole him to keeping on the job.

JOB SCHEDULE INSURING SUSTAINED ATTENTION OF LOOKOUT

A job designed to meet these requirements is the systematic recording of the visibility of selected points at varying distances and directions from a lookout. Such observations will form the basis for answers to many questions that are now unanswered. One of the most important of these is the effective range of visibility. If the lookout is required to observe intently and note four times an hour whether a designated point is fully, partly, or not visible, and if he keeps track of 10 to 20 such points, basic requirements for meeting the required detection service will be largely fulfilled. In the process of looking at 10 to 20 points, his eye will automatically cover his territory. This task is entirely feasible for him to do, is intrinsically interesting, and is not merely a burdensome paper record. Through this means, lookout detection can be converted from mere subconscious effort to one of conscious, systematic observation involving judgment in determining one of three possibilities, which can be checked internally or by comparison with the records of neighboring peaks. The average lookout is honest enough to carry out his job; what is needed is quality of observation as well as quantity. The plan proposed automatically insures both, because the man must form a judgment as to which one of three possibilities in visibility is true for each point selected.

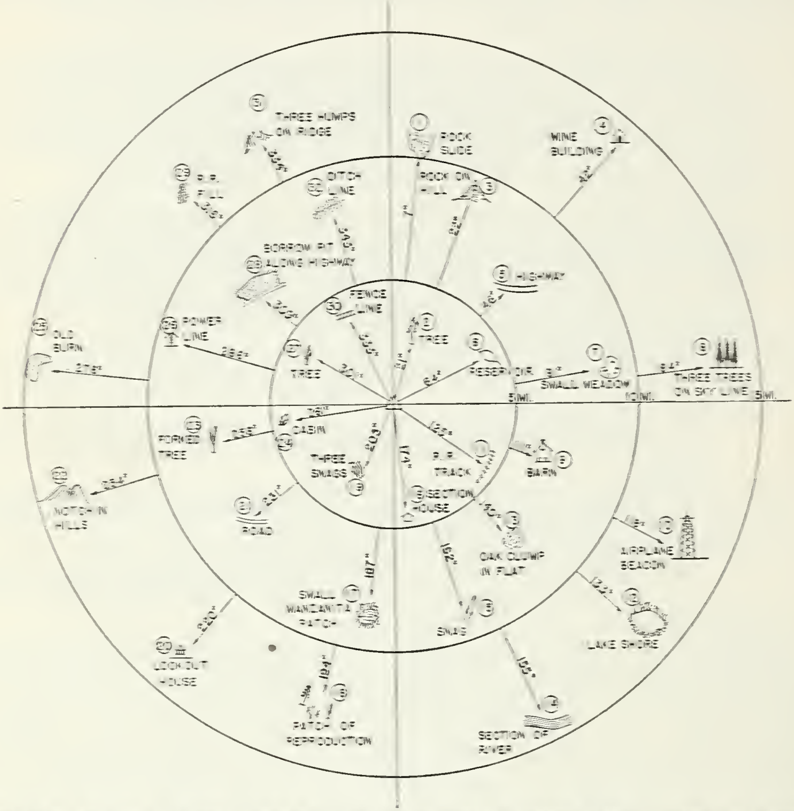

FIGURE 19.—Visibility "target", showing a succession of objects at varying distances around the azimuth circle upon which the lookout is expected to report at quarter-hour intervals as to degree of visibility and cause of poor visibility.

Figure 19 illustrates a method of setting up systematic observations and of drawing attention to conditions of atmospheric visibility, which has been recently adopted in portions of the California National Forest Region. The study has two purposes: First, it provides a means of reminding the lookout of the necessity of covering all portions of his visible area at regular intervals; secondly, it provides a method of obtaining a current and seasonal record of atmospheric visibility.

The first step in undertaking the study consists of preparing the visibility diagrams. A forest officer visits the peak in clear weather and chooses 20 to 30 objects of varying distances and in all quadrants of the azimuth circle. Consecutive numbers and azimuth readings are recorded on the diagram. The attempt is made to pick objects which are plainly visible when the atmosphere is clear, to serve both as key points of fire risk, like check stations to a night watchman, and also as representative visibility targets. Varying the distance of the targets around the circle further encourages alertness in observing near and distant areas.

The lookout is ordered to record the visibility of all objects at 15-minute intervals from 8 a. m. to 6 p. m., on a form provided for the purpose on which each target is given a column and each quarter-hour interval a line. In each column of the form is recorded the visibility of the object under three classifications, designated √—(plainly seen), O—(dimly seen), and X—(not visible). The lookouts are requested to report also in the same blocks the reason for poor visibility. The code adopted for this record is 1 (looking into sun), 2 (haze), 3 (drift smoke), 4 (smoke from going fire), 5 (industrial smoke), 6 (shadow), 7 (fog), 8 (storm), and 9 (cloud shadows). An object numbered 1, invisible at 11:15 because of smoke from a going fire, would be recorded by placing the code letters X4 in the first column opposite 11:15.

The observing and recording at first go slowly, until the lookout memorizes the number and location of his targets and becomes accustomed to recording their ratings in groups rather than singly. Then the chart is no longer used and it becomes a rapid and systematic performance by which he is actively observing all his territory and noting down the information only incidentally. In this way the operation usually requires less than 5 minutes and it is possible to set up a routine of 5 minutes of intensive search, then 10 minutes of rest.

One sheet of the form is required for each day's observations and the used forms are returned to the supervisor's office at regular intervals. The resulting data for each visibility target cannot be used directly as a measure of the visibility of smokes, since the direction of illumination from the sun affects the visibility of a smoke column differently from its effect on that of a natural object of the landscape; but it is possible to make the combined current record of several lookouts into a sensitive indicator of atmospheric conditions. A daily record of this kind maintained by the dispatcher for a short period in clear weather soon establishes the normal daily fluctuations. Variations above or below these trends then become valuable as a measure of effective radius of vision.

This method of systematic observation goes far to solve the real problem of relieving strain, which is to train the lookout man to take short but frequent rests during the day. The novice is usually obsessed with the idea that he must scan the country constantly and intently. If he actually does so, fatigue will be severe by midafternoon when he should be at his highest level of efficiency. If he persists day after day, something approaching a break-down is inevitable.

The art of observation depends first of all on a certain routine in the order and direction in which different parts of the circle are observed. It depends on an unconscious picture in the lookout's mind of the normal appearance of each sector and the instant detection of any departure from that normal. To a skilled observer, the detection of smoke is not a matter of intent, long-continued peering, but is an instinctive reflex like that of the trained mechanic whose ear detects instantly any abnormality in the functioning of the gas engine. A quick running glance moving from near objects to distant ones, if it covers the ground systematically, represents not only the minimum of eyestrain but the most effective way to detect smoke. Staring fixedly at a landscape, on the other hand, not only is fatiguing but tends to encourage optical illusions. Only after the lookout suspects that he sees something different or unusual is intent watching necessary. On the whole a skilled observer can cover his territory with satisfactory completeness and regularity and can record definite observations on visibility of selected points in probably one-third of the total time he is on duty, permitting ample time for periodic relaxation from the strain of observation. This in turn removes any necessity for complete relief for longer periods.

OTHER METHODS OF INSURING SYSTEMATIC OBSERVATIONS

Attempts to accomplish systematic observation through the periodic use of an alarm clock by the lookout to remind him to scan the horizon at a particular moment, or through frequent calling of the lookout man by the dispatcher for the same purpose have not been successful. Both these devices have the inherent weakness that they are obviously based on lack of confidence which fails to give a real incentive for honest performance. Moreover, there is no real way of checking whether the lookout does take a look after the bell rings, regardless of formality in recording his action.

There are other possibilities for overcoming obstacles to satisfactory performance. A very important one is to give the lookout job the flavor of a competitive game. This can be accomplished by keeping him informed of his first discoveries in other lookouts' territory, of other lookouts' first discoveries within his territory, the accuracies and inaccuracies of his location, and the size, character, and spread of local fires. This will require systematic handling by the dispatcher. Alertness can be inculcated by smudges set for the express purpose of testing the lookout. There should be no hesitancy in informing lookouts when this is being done.

Inspection by the ranger and other visiting forest officers should be frequent enough to satisfy in some degree the requirement for human contacts on the lookout's part.

Two blanket methods of overcoming difficulties inherent in lookout service have been proposed and tried. The first of these is to place two observers on each peak to act as alternates or to check each other. The cost of this, if done on a large scale, would be considerable and it does not, in fact, take care of several of the most serious difficulties. Two men on one point can commit the same errors of omission. It cannot be recommended as a solution of the lookout-personnel problem. A variation of the two-manned lookout position is using a married couple. This is desirable where it can be done, but should not obscure the necessity for doing the other things outlined.

A plan of systematic relief of lookouts for 4 days each month was in use at one time but has been abandoned for several reasons. These are (1) the very great administrative and financial difficulty in putting it into effect; (2) the fact that the best lookouts who presumably needed relief did not want it and preferred to retain the relief man as a mere visitor; and (3) lack of evidence that this assured better detection service.

Among other tasks that break the monotony of the job, reduce fatigue, and prevent flagging of interest, are the regular measuring and recording of weather conditions or systematic reporting to the dispatcher.

During and after lightning storms, when continuous observation is needed, most lookouts are so intent and alert that there is no problem in keeping them on the job and they are not conscious of nor worried by fatigue. This undoubtedly is one reason why lookouts detect a much higher percentage of lightning fires than of man-caused fires. The real problem of obtaining attention and of avoiding fatigue is during the long protracted periods when nothing particular is happening. It is for these periods that formalizing the lookout's work is so essential.

CHECKING LOOKOUT PERFORMANCE

Complete information as to the territory seen by each lookout is essential to any systematic method of checking lookout performance. Accurate visible-area maps are needed for this purpose and should enter in this way into current use. For checking by the dispatcher they should be combined into a composite map showing by key number all territory seen by each lookout. Further identification of the territory visible to each lookout is accomplished by using a three-color scheme, such as yellow for territory seen by one lookout, green for territory seen by two lookouts, and orange for territory seen by three or more lookouts. With this map the dispatcher can determine at a glance which lookouts should have reported any particular smoke within time limits and usually which should have made the first discovery. If it is necessary for the dispatcher to call the lookout and ask him for confirmation of a previously reported fire within his visible territory, this should ordinarily be charged against him as a failure. The dispatcher should, of course, take account of any abnormally bad visibility conditions. Where fires are reported by outsiders or others who were in close proximity to the fire and where the smoke has not risen above the trees, the dispatcher should be cautious in charging a failure to the lookout. A complete current record of each lookout's performance on all his chances should be kept as a basis for decision as to retention or dismissal. No fixed percent batting average can now be set up which would be uniformly applicable, although it certainly should not be less than 80 percent of the opportunities for detection.

Another possibility for current check is through surprise tests by means of smoke bombs, smudges, and occasionally industrial woods fires. Performance on these should be recorded on the individual records.

Inspection by the district ranger, as previously outlined, will in itself ordinarily disclose the seriously incompetent. Above all, the checks made should determine whether the lookout is fulfilling his primary function of discovering and locating fires promptly. Other duties must also be currently checked but are less important.

THE COST OF ADEQUATE DETECTION BY LOOKOUTS

Provisions for adequate detection have seldom been studied from the point of view of an investment charge designed to give an adequate return in reduced damage and suppression costs. Owing to the important elements in assumed damage that must always be rated as "intangible", and to the fact that fires "nipped in the bud" attract little attention and defy any close estimate as to what the result of delayed detection would have been, it will probably always be difficult to determine exactly what investment charges will be justified.

From the systematic detection-planning work carried on in California, three phases of the question have, however, been made clear: (1) An adequate lookout system must be recognized as a major investment; (2) a partial-detection system carries heavy liabilities, since below a minimum level time-control standards are uncertain; and (3) as this level is approached the law of diminishing returns applies sharply, requiring careful plans by major units to reach the level within reasonable costs.

If the results of approved detection plans are considered for the 11 northern California forests, some of the aspects of cost can be examined more specifically. In these 11 forests, systematic detection plans resulted in a rearrangement and a net increase of 87 positions giving lookout service, over 132 former positions. Of these, 90 in the old system, 128 in the new were rated as detection positions exclusively, and 42 and 91 as lookout-fireman positions. Many others in the new system will contribute directly to fire suppression through administrative provisions such as the employment of married men or other arrangements for quick replacement of a lookout sent to a fire. Average annual cost of a lookout may be figured on the following basis: Five months' services at $110 per month, $550; 10-percent maintenance and amortization on capital investment of $1,750, $175; total, $725. If 50 percent of the lookout-fireman positions are assessed against detection this gives a total equivalent of 111 positions in the old system and 174 positions in the new charged to detection. The increase in total cost is then from $80,475 to $126,150, or about 50 percent. With this increase, seen territory was increased from 7 to 10 million acres. On this basis the cost per acre of directly seen territory increased only from 1.15 cents to 1.26 cents, or 0.1 cent. If the cost is assessed against areas in established risk zones only, the increase in cost of a 33-percent improvement in coverage is only from 4.1 cents to 4.6 cents per acre. The detection charge spread over the gross area increased from 0.5 cent to 0.7 cent per acre. The indicated detection cost per fire in seen territory, based on past history, increased from $142 to $165. Based on the 1921–30 average number of fires in the whole territory concerned, the indicated detection charge is $106 per fire. Other data indicate that a resulting saving in average annual cost and damage of approximately 15 percent will fully justify the entire investment.

Each forest unit and the localities within it present distinctive topographic and other features that influence both the cost and the scope of adequate fire detection. Topography controls the feasibility of complete coverage by a reasonable number of lookouts. In the plateau type where isolated buttes and mountains occur, as represented by a considerable territory east of the Sierras, a few lookouts can cover a great area of dispersed risk. One lookout characteristic of this type of topography covers directly 67.5 percent of the total territory within 15 miles of the lookout or 440,000 acres. Using the $725 per year for the cost of operation, this represents an annual detection cost of only 0.16 cent per acre. In this type of country, the lack of distinctive landmarks makes accurate location of fires by one lookout difficult, and adequate detection can be assured only if cross shots from other lookouts are available. This in practice means that this cost would be at least doubled, a figure still very low.

The Sacramento Canyon unit of the Shasta National Forest is an excellent example of territory in which detection coverage is difficult to obtain. This was the first unit for which a thorough and detailed analysis of the detection problem was made. It includes the headwaters of the Sacramento River and consists largely of sharply cut topography with winding, narrow canyons, numerous irregular ridges, and a range in elevation within hazard zones of 1,000 to 8,000 feet. The man-caused risks are intense and are distributed as a heavy band up the Sacramento Canyon through the center of the unit with tributary fingers up each accessible side drainage. The high country carries a lightning risk, little of which can be sufficiently defined for inclusion in established zones. The total area of the unit is 487,000 acres.

To date, the area of established fire occurrence zones amounts to 131,000 acres, or about 27 percent of the total area. This 27 percent represents territory in which occurrence has exceeded 1 fire per thousand acres over a 10-year period.

Detection service formerly was furnished by three primary lookouts, each contributing to adjoining areas, so that a total of only about one and one-half lookouts were properly chargeable to the unit. This service has direct coverage of 53 percent of the 487,000 acres in the unit, but of only 33 percent of the 131,000 acres of established risk area. Using $725 as the annual charge per lookout, the former annual cost would be $1,085. Table 2 shows the per-acre proportionment of this cost for the various areas considered.

Table 2.—*Comparison of results of reorganized detection service on Sacramento Canyon unit, Shasta National Forest*

Item	Former	Present	Approximate increase (percent)
Total area ... acres	487,000	[1] 487,000	
Area of established risk zones ... do		131,000	
Lookouts ... number	1.5	7	367
Total area seen ... acres	258,000	318,000	23
Risk area seen ... do	44,000	89,000	102
Total cost ... dollars	1,085	5,075	368
Cost per acre, total area ... cents	.22	1.04	373
Cost per acre, seen area ... do	.42	1.60	281
Cost per acre, risk area ... do	[2] .83	3.87	366
Cost per acre, risk area seen ... do	2.47	5.70	131
Cost per fire in seen area ... dollars	33	65	97

[1] About 27 percent of total area, in which, during 10 years, fire occurrence has exceeded 1 per thousand acres.

[2] Based on present coverage.

The detailed study showed that in order to come reasonably close to covering the known risk areas, a total of seven primary lookouts was needed, of which only one was then in use. This detection system, now in full operation, covers 318,000 acres or 65 percent of the whole area of the protection unit and represents a detection investment 4.7 times that of the former system. It covers in all 89,000 acres or 68 percent of the acreage of established risk, but this represents 78 percent of the computed total risk. It is notable that when the lookouts were increased to nearly five times their former number, the per-acre cost in terms of risk area seen was little more than doubled.

The necessity for so intensive and complete a detection system was indicated by the fact that practically all of the established risk area in the unit is within cover types for which ¾-hour control is needed and by the fact that the average annual number of fires for the unit has exceeded 100 in the last 10 years, almost entirely of man-caused origin. This is reflected in the low detection charge per fire given above. Despite a very intensive guard system and rapid travel time going to fires, the handicap of exceedingly slow discovery under the former lookout system resulted in 138 class C fires, with correspondingly high burned areas, cost of suppression, and damage. Of the 138 C fires which occurred in this unit from 1921 to 1930, 112 started in the blind areas. With the new system, only 20 of these C fires would have started in blind areas.

The special need for providing continuous and intensive detection in this unit of rugged topography gave an excellent demonstration of how the law of diminishing returns may apply under such conditions. In addition to the natural difficulties of covering a large acreage from any one lookout point in such country, the risk zones of first concern in this unit occupy the canyon bottoms and lower slopes, many of which are visible from local points only. The result is reflected in the following comparison. In the original detection system of one and one-half lookouts, as shown in table 2, the average covered per lookout was 29,000 acres of risk zone and 172,000 acres of total seen area. Under the planned system, each lookout averaged 13,000 acres of risk zone, out of 45,000 acres seen. The last three lookout points chosen averaged only 6,000 acres of new territory each, or less than one-fifth of the area covered by the last peak to be selected in the unit reported in table 1 (p. 20). This greatly diminished net coverage of added lookouts as the system approaches a satisfactory standard, in localities of difficult topography, illustrates the importance of an index figure of area weighted by frequency of fire occurrence, in determining the value of any given point, in preference to an arbitrary criterion of area alone.

The value of obtaining double coverage tends to offset this rapid decrease in unduplicated coverage by one lookout. The method of weighting the value of coverage by the degree of risk tends to draw detection positions toward the high risk areas. Consequently, the duplication falls largely in these important areas and accomplishes automatically the balance necessary. In the planned detection system of seven lookouts for the Sacramento Canyon, 65 percent of the seen area was covered by two or more lookouts. In the detection program as a whole the degree of duplicate coverage falls below this 65 percent, but increases in the danger areas and represents an item of much increased efficiency not reflected in the cost figures used for comparison. Any attempt, however, further to increase double coverage uniformly would greatly increase the number of lookouts and the cost for the detection unit.

The cost of adequate detection will vary between extremes of 0.3 cent and 2 cents per acre for territory actually covered directly and, on the basis of California forests as a whole, will average approximately 4 cents if assessed entirely against the area in established risk zones. Experience in the entire group of forests in the California Region indicates that a detection charge of 1 cent per acre is to be expected to meet minimum requirements and, as a general guide, this may be reckoned as 10 to 15 percent of the total protection cost.

APPENDIX

USE OF PHOTOTRANSIT CAMERA AND PROFILER

As outlined on page 18, the first work in California in making visible-area maps by means of phototransit pictures followed the general technique of the field-sketching method, substituting photographs, protractors, and scales for the actual landscape and field-sketching instruments. This procedure proved to be slow and difficult; distant topography is hard to identify in a picture and was often obscured by haze when the picture was taken. Accordingly much of the procedure of the profile method (p. 5) was introduced, and a technique was evolved that combined the profile method with modified field sketching. Such a combination was made feasible by the perfection of an instrument, especially developed for this purpose, called a "profiler" (fig. 20).[5]

The slide A of the profiler has on its left edge a vertical scale giving elevations and on its right edge a scale indicating vertical angles. The elevation-scale calibrations are fixed but are numbered for each map with reference to the elevation of the observation point. The elevation of the observation point is the value of X on the A scale. From X the numbering progresses up or down, depending on whether the vertical angle is plus or minus, and remains unchanged until the observation point is changed.

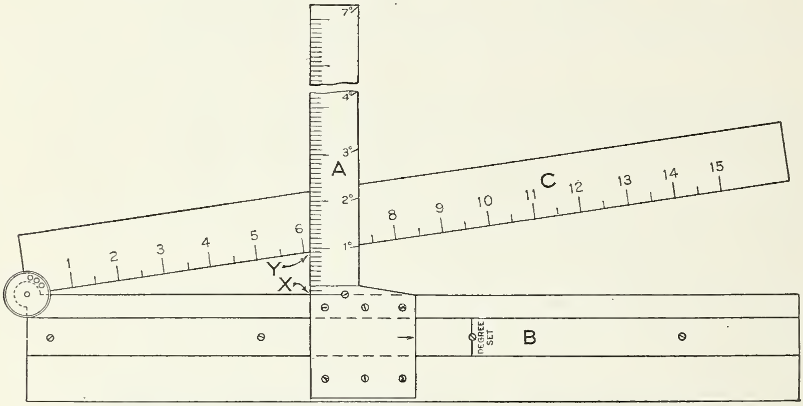

FIGURE 20.—Profiler developed for making visible-area maps from photographs.

The vertical line of sight bar B has a track that maintains A perpendicular to B. There is a mark on B called the "degree set", at which the slider A must be placed when setting the instrument for vertical angles.

The horizontal line of sight, or azimuth arm C, is graduated in miles for the map scale that will be used and is so hinged to B that their pivot point is the intersection of their inside edges. When the hinge is centered over the observation point, the arm C acts as a base. A, B, and C are transparent celluloid. To facilitate azimuth determination, the arms B and C may be pivoted at the center of a large protractor of radius equal to the range of visibility to be mapped (15 miles in California). The procedure in making the visible-area maps is as follows:

A section of topography easily recognizable on the map is selected in one of the pictures, the azimuth through a prominent point is determined, and a line is drawn through this azimuth on the map. The profiler is centered on the observation point with the inside edge of arm C fixed on this azimuth. The vertical angle at the top of the first obstruction to the line of sight in the photograph is read from the photograph. The A scale is slid to the degree-set position, and this vertical angle is set off on the vertical-angle scale by adjusting the arm B so that the correct reading on A is at the lower edge of the C arm. With the angle between B and C thus set, the A scale is then slid along on the B arm and a check made between the penciled elevations on the left edge of A and the map contours along the azimuth laid out. At the first point beyond the obstruction where these scale readings become smaller than the map elevations (Y), the country is emerging above the line of sight. This marks the beginning of seen area behind the obstruction, and from this point a colored pencil mark is drawn to the next obstruction evident from the photograph and the map.

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[5] Developed by Nelson D. Salmon, technician.

A new vertical angle is then taken and the process is repeated. If the obstruction is difficult to identify by inspection of the photograph a check of its vertical angle will quickly identify it on the map. Or, if the vertical angle is indefinite, map elevations may be used to set the angle. Map errors become unmistakable and can be prevented from contributing large errors to the visible-area map, just as in field sketching. For mapping of the immediate foreground, where mechanical methods are unsatisfactory, inspection of the photograph is the chief dependence. Azimuth is used as in field sketching to tie in horizontal limits. As new profiles are added, the possibility increases of effective sketching directly from the photograph, making it unnecessary to follow through all the mechanical details. A large reading glass is helpful in interpreting details of the picture.

The time required to make visible area maps by this method, once the pictures are available, is greater than that taken by an experienced field sketcher on the ground, but it is less than that required with a profile board and the results are more accurate.

Several objections are evident to standardizing this method for lookout planning in California. Field data, such as the kind and cost of improvements needed to develop the lookout site, the height of tower necessary, etc., would have to be obtained on the ground when the picture was taken. Furthermore, in order to obtain a full panorama from a point that has not been improved for lookout use, it is usually necessary to set up the camera several times, resulting in a panorama not identical with the view to be obtained later from the lookout house, particularly if the house is to be placed on a tower. This necessitates the time and expense of a later retake from the improved point, for permanent use. The phototransit camera itself is heavy and not well-adapted to packing into inaccessible territory, a serious consideration in any attempt to map freely all the potential observation points in a given area.

The application of this method of developing visible-area maps is accordingly limited to peaks already improved as lookout points or known to be relatively unobstructed, and is therefore not suitable as a substitute for either profile sketching or field sketching in any such comprehensive lookout-planning program as that undertaken in California, involving the systematic investigation of all possible lookout sites. It has, however, certain intrinsic advantages that permit profitable application under certain conditions. Unlike the profile method, it enables the mapper to use "actual" vertical angles direct from the picture, and to avoid serious errors in the vicinity of the lookout point, advantages which are otherwise peculiar to field sketching. At the same time the sketching can be done independently of weather and field travel.

Accordingly, if phototransit pictures are already available, lookouts are already established, and further extensive field work is impossible, it is recommended as a means of building up or of keeping up-to-date an accurate record of the territory covered by lookouts.

CONSTRUCTION AND USE OF RELIEF MODELS

Relief models are constructed by tracing each contour or every other contour upon bristol board, or some similar material. The board is then cut along the traced lines, giving a series of irregular shaped boards which correspond to horizontal sections of the topography. The vertical scale of the map is controlled by the thickness of the wallboard used. With ⅛-inch board and 100-foot contours, the scale will be 8.125 inches=100 feet if each contour is traced, and 0.125 inches=200 feet if every other contour is traced. This results in an exaggerated scale which is desirable in a relief model. When all the contours are cut from the board, the relief model is constructed by placing the lowest contour on the work table and tacking to it the next higher and continuing until the highest contour is reached.

The next process consists in smoothing the model with clay. A plaster-of-paris cast may now be made of the completed model, and from this negative as many duplicates as desired may be struck.[6]

After the relief model is constructed, the visible area of any point may be determined by mounting a small bulb directly on the point and making a permanent record of the areas lighted (visible areas) and areas in shadow (invisible areas). For best results this work should be carried on in a darkroom or at night. The filament of the light should be placed as close to the point as possible. If it is 0.125 inch above the point on a map with a vertical scale of 0.125 inches = 200 feet, the net result will be a picture of visibility from a 200-foot tower on the point. Shaving off the top of the point on the model may be resorted to when an accurate record is desired.

Two methods of making a permanent record of the lights and shadows have been used. One method consists in placing a sheet of glass over the model and transferring lighted areas to this surface by the use of colored paints or china-marking pencils. Care must be taken in tracing that the eye and the pencil are vertical over the area being recorded or inaccuracies will result. After the visible areas are recorded on the glass, they may be transferred to permanent record by retracing on paper. This procedure is time-consuming.

The second method consists in lighting each peak in succession and recording the visible area by a series of photographs, one for each point. In this method, skill and special equipment are necessary to eliminate distortion. To obtain permanent records on the scale desired the negatives may be used to construct ordinary projection lantern slides. These slides may then be projected to any desired scale on a base map, and the visible areas outlined.

These methods require so much special procedure and technique that they are of interest chiefly for demonstration purposes.

The light-and-shadow relationships of a relief model are, however, in themselves a most valuable means of training the eye to translate the portions of topography seen in the oblique into flat projection on a map. Advantage was taken of the graphic values of these light-and-shadow relationships in training visible-area mappers for the California work.

The most practical and valuable service that may be gained from a relief model is in the preliminary reconnaissance of points of possible detection value. A very small light placed progressively on all vantage points of the model creates the characteristic pattern of light and shadow represented by a visible-area map from each. This gives a quick visual picture of the extent and potential importance of visible area in each case and rapidly identifies the points of most importance. A great deal of fruitless work in the field can be eliminated in this way. In the same way, it is often possible to select the best point to cover a particular locality when the relationship is not very apparent on the ground. Where travel on foot is very slow and difficult as in the chaparral forests of southern California, study of a relief map becomes a very important and valuable preliminary measure in carrying out a detection planning program.

USE OF PUNCH-CARD SYSTEM IN EVALUATING LOOKOUTS

The method of evaluating lookout points described in the body of this circular gives emphasis to the area of risk territory covered rather than to the exact location or identity of the territory. Consequently, it is possible to treat a whole protection unit as a pool of so many area units and to represent each by a separate punch card. Each area unit, and so each punch card, then becomes a least common denominator for all data, giving great flexibility to this system of evaulating lookouts. As developed and applied in actual planning in California, the method and such elements of its technique as may be of value in similar work are here described.

CODE PLAN

The first and most important task in undertaking evaluation by tabulating machine methods is the setting up of a code plan. The plan must be based on a clear knowledge (1) of the combinations and correlations of data needed and of their relative importance as control factors in the study, and (2) of the operation and full potentialities of the punch-card method.

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[6] Many of these models for California areas have been made for various purposes under the supervision of H. A. Sedelmeyer, chief of drafting, U. S. Forest Service, San Francisco, and in the laboratories of the National Park Service. Detailed instructions are available from these sources.

If the officer responsible for the project has the first requisite only, he can himself determine the adaptability of his project to punch-card methods and, through the help of a tabulating-machine representative or a trained operator, can soon develop an effective code plan.

In setting up the plan, the smallest unit of measurement necessary to meet the standards of accuracy desired must first be determined. This is an important decision, since the unit adopted must serve as the base of all computations, and determines the margin of error and the total number of cards necessary.

In theory the 40-acre subdivision was adopted as meeting these requirements. In application, however, a considerable portion of the areas classified was of low value both in risk and hazard. Here description by 160-acre subdivisions was sufficient for the purpose. Consequently, wherever a whole 160 acres fell in this class, it was represented by only one card instead of four. Figure 21 gives the punch-card form. Following the tabulating sheet number (3 columns), 7 columns were used for identification. Township or range or both, 1 digit each, or a maximum of 2 for both; section (as 01 to 36), 2 digits; quarter-section, numbered from 1 to 4, 1 digit; the forty, 1 digit. To insure speed and accuracy, in calling off the identification of the quarter-section and 40, etched squares of celluloid carrying the standard code numbers in the proper rotation are moved along over the map. Irregular sections are set up to the nearest 40 only. Where a card represents a full 160, the figure 9 is used in the 40 column as a means of distinction. In the coverage columns it is punched as 4, while forties are punched as 1. In the sample code sheet shown (fig. 21) the 160's were punched to the nearest 40 of coverage 1 to 4.

Following these identification columns, the descriptive classification data are set up. One column identifies risk zone, one gives the number of fires that have occurred in the period used, and one identifies hazard class. Hazard class was not used in the sample shown (fig. 21). Then with identification and the classification of fire danger properly assigned, the remainder of the card can be devoted to coverage obtained by prospective lookouts to be tested for detection value within the unit. One column is assigned to each and wherever a particular 40 is covered this is recorded by a punched 1 for each lookout contributing to this area. If it is desired to classify coverage, for example, within two distance limits, this can be accomplished by using two columns and recording coverage to an 8-mile limit in the first and to a 15-mile limit in the second.

TABULATING DATA

All data should be assembled on tabulating sheets prepared for the purpose before the punch cards are made (fig. 21). This procedure is of considerable advantage if the data must be assembled from various map sources and brought together for the first time on the tabulating sheets. Where the information is available through intensive surveys, such factors as property value, elevation, percent of slope, volume of timber, quality of soil, can also be brought to bear upon the results of the analysis. A 40-column card provides enough space for a very complete classification in small fire-protection units. The limitation in card space needed is fixed by the number of lookouts to be evaluated.

Tabulating the base map by 40-acre subdivisions is the laborious part of the job. After this is accomplished, entering the coverage by lookouts on the tabulating sheets goes very rapidly. A 40 is entered as covered if half or more is visible. The quarter-sections may be split and entered to the nearest 40 if column totals rather than card counts are used; otherwise, treat like 40's. In 60 to 90 minutes two people working at the tabulation can enter completely a visible-area map of 15-mile radius.

PUNCHING AND CHECKING

With the data all coded on the tabulating sheets, all is ready for punching on the cards. An experienced operator can turn out about 1,400 cards per day from tabulating sheets. When completed, the cards must be listed by the tabulating machine and printed as punched to check for errors. Checking between the printed tabulation and the original sheets is always necessary and is rather time-consuming.[7] Once this is completed and errors corrected, everything is in readiness to begin the actual machine evaluation. Enlarged samples of the card showing the identity of each column must be posted for constant reference if blank cards are used.

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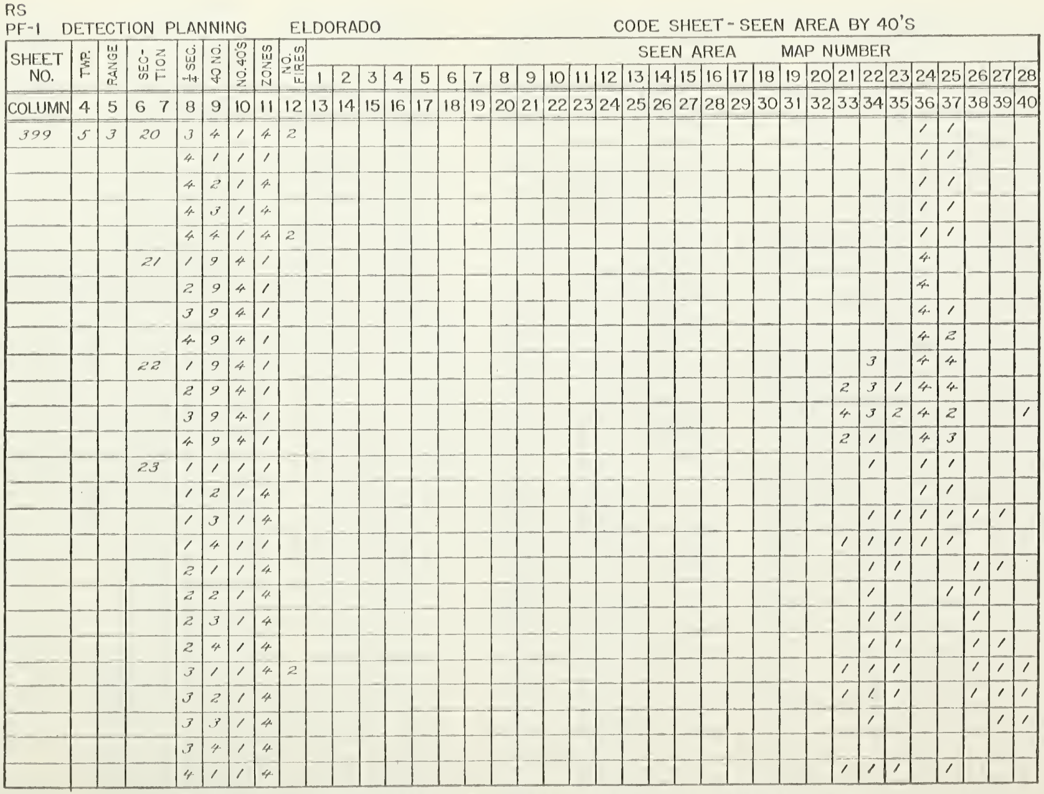
[7] Checking can be done by the use of a verifying machine which requires only one clerk instead of the two required to compare sheets. The verifying machine is similar to the key-punch except that it has solid punches.

MACHINE EVALUATION

The first determination is that of obtaining all totals for the unit. For this, all cards are sorted by hazard class within risk zones and the total number of fires and of 40's obtained for each class. From these totals the average fire occurrence for each zone is available and a sufficiently dependable area figure is derived for each class of data so that planimetering of the original maps can be eliminated. These final figures, just as obtained from the machine, may be termed "table 1." From it the weight assigned to each risk zone in proportion to its fire occurrence is easily computed and is converted to a basis of weight per 40 acres.

After the totals are set up, a sort is made for the gross coverage of each lookout. If the sorting machine is equipped to give card counts directly, this procedure is very simple. If the tabulating machine itself must be depended on to give the totals, it is a little more complicated. The procedure is to sort all the cards for



RS
PF-1 DETECTION PLANNING ELDORADO CODE SHEET - SEEN AREA BY 40'S

									SEEN AREA MAP NUMBER																											
SHEET NO.	TWP.	RANGE	SEC-TION	¼ SEC.	40 NO.	NO. 40'S	ZONES	NO. FIRES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
COLUMN	4	5	6 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
399	5	3	20	3	4	1	4	2																								1	1			
				4	1	1	1																									1	1			
				4	2	1	4																									1	1			
				4	3	1	4																									1	1			
				4	4	1	4	2																								1	1			
			21	1	9	4	1																									4				
				2	9	4	1																									4				
				3	9	4	1																									4	1			
				4	9	4	1																									4	2			
			22	1	9	4	1																							3		4	4			
				2	9	4	1																						2	3	1	4	4			
				3	9	4	1																						4	3	2	4	2			1
				4	9	4	1																						2	1		4	3			
			23	1	1	1	1																							1		1	1			
				1	2	1	4																									1	1			
				1	3	1	4																							1	1	1	1	1	1	
				1	4	1	1																						1	1	1	1	1			
				2	1	1	4																							1	1			1	1	
				2	2	1	4																							1			1	1		
				2	3	1	4																							1	1			1		
				2	4	1	4																							1	1			1	1	
				3	1	1	4	2																					1	1	1			1	1	1
				3	2	1	4																						1	1	1			1	1	1
				3	3	1	4																							1					1	1
				3	4	1	4																													
				4	1	1	4																						1	1	1		1			

FIGURE 21.—Sample code sheet used in evaluation of lookouts by punch-card system.

the unit by risk zone and for hazard class within each, then to obtain the total coverage of each lookout classified in this way in the form of card counts. With an automatic card counter this can be done simultaneously for all lookouts included in the tabulation. The net result for either method is the total coverage in acres for each lookout and the amount of risk and quailty of hazard represented in this coverage without any account being taken of duplications between points. These gross values, when rearranged in order of value, serve as a second table of the machine tabulation. Since this table defines both the quantity and quality of the potential coverage from each lookout, it permits the selection of the lookout of greatest value. As soon as this initial point is selected, the cards for the unit are run through the sorter to take out all the area credited to this point. Another total is then made with the remaining cards, which gives another table similar to table 2, giving now the net coverage of the remaining points with all territory eliminated that has been covered by the first one selected. This third table enables the selection of the second point.

In the California units this process was repeated down to the point where none of the remaining lookouts had sufficient value to meet the requirements of a 25 rating established by the studies. When the selection has been brought to the point of diminishing returns in this way, it is very easy to determine the net coverage of each of the accepted lookouts in competition with each other by taking the block of cards that has been removed by each successive point and mechanically sorting out all of them that were covered by the others. The obtaining of net unduplicated values, which is very difficult by planimetering, becomes in this way a very interesting check, easily accomplished. The cards have the advantage of a high degree of flexibility and wherever close decisions are involved it is very easy to set up various combinations and to check the final net result of alternative systems.

With the work completed in this way it is then necessary to return to the original maps and to make up a composite tracing of the points set up. Under this composite tracing the various maps can be compared visually so that little of the demonstration value of the original method is lost. Final results of evaluation by this method have already been shown for the Mendocino National Forest in figure 11.

VALUE OF THE METHOD

Since hand compilation and machine tabulation were not done on the same units, it is difficult to compare accurately the time and cost of lookout evaluation by punch cards with that by the hand compilation and planimetering method. The work done, however, indicated a saving of approximately 50 percent in the speed of the work in favor of the tabulating machine and about 20 to 30 percent in the probable total expense. A unit of 1 million acres would require about 3 weeks' time on the part of the man in charge, and about 2 weeks' time on the part of an assistant. When the complete code plan has been set up and instructions prepared for the method of procedure, one person trained in the use of the machines can handle the whole job with clerical assistance only. About $100 to $150 in direct machine costs would be involved, plus about $60 for the services of a punch-card operator, and about $15 for 13,000 cards.

The particular value of the machine method of evaluation is its adaptability. The more detailed and intensive the study contemplated, the greater its potential advantage. In this particular study, had the machine method been introduced earlier in the work, more factors could have been correlated and a more intensive study carried through for the same expenditure. Consequently, careful study should be given this method in similar work involving mathematical ratings of a more complex or detailed nature.

The particular features of the hand compilation that were eliminated by the machine method are (1) all planimetering, (2) the making of visible-area tracings, (3) the reduction of all map data to identical scale and base and their assembling, and (4) the checking of computations.

However attempted, a complete study of detection coverage must be recognized as a task of major project proportions and planned for accordingly. The code method offers a rapid means of carrying through such a study when mathematical rating schemes result in complex or burdensome computations.

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